BRITISH ORTHOPAEDIC ASSOCIATION: FIRST FOUNDERS' LECTURE

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" Ere the parting hour go by,
Quick, thy tablets, Memory! "
To my friends—Matthew Arnold

I am deeply conscious of the honour you have done me in inviting me to give this, the first Founders' Lecture. I have no doubt that your choice was influenced by the fact that of the three surviving Founding Fathers—Sir Thomas Fairbank, Mr Arthur Rocyn Jones and myself—it fell to my lot to be the first Honorary Secretary of the young Association launched forty years ago. The story of the growth of the Association from small beginnings in 1918 is a chapter in the history of the evolution of orthopaedic surgery in Great Britain during the first half of the twentieth century. Some of this story has been admirably told by Mr Rocyn Jones in his Presidential Address to the Orthopaedic Section of the Royal Society of Medicine in 1937, and more recently by Mr H. Osmond-Clarke in the special commemorative number of our official Journal in 1950. But, unlike the elephant, " young men forget "; and some of the events of those early years will, I hope, bear repetition—and perhaps embellishment—when related by one who was an eye witness of the scene.

At the turn of the century orthopaedics in Great Britain occupied an unimportant position as a differentiated speciality within the realm of surgery, and by common consent its field was limited to the correction of established deformity. The great mass of deforming diseases and injuries was at that time treated by general surgeons in general and children's hospitals. Amongst the forty original members of the short-lived British Orthopaedic Society founded in 1894, there had been a mere handful of surgeons who practised orthopaedics exclusively. But in the decade before the outbreak of the first world war the scene had begun to change, and the stage was being prepared for the launching of a new specialist association. In London the three independent and rival charities, the Royal, National, and City orthopaedic hospitals—all institutions of small size—had merged in the new Royal National Orthopaedic Hospital, opened in Great Portland Street in 1909. Of the five surgeons brought together on the staff of the combined hospitals, two only were orthopaedic surgeons and nothing else—Mr E. Muirhead Little and Mr Evan Laming Evans. A. H. Tubby, well known for his writings, T. H. Openshaw, and J. Jackson Clarke, were also general surgeons at the Westminster, the London, and the Hampstead General respectively. It was true that at St Bartholomew's an orthopaedic department, so-called, had existed since 1864; but until 1912, when Mr R. C. Elmslie was appointed to take charge, the department had been simply a special out-patient clinic conducted by one of the assistant surgeons of the hospital. Of these, one who made notable contributions to the literature of orthopaedics was Howard Marsh. In 1906 the Charing Cross Hospital had unwittingly made history by creating a department with a few beds under H. A. T. Fairbank, who had already begun to achieve distinction in children's orthopaedics at Great Ormond Street. At Guy's also orthopaedics was emerging from its subordinate status under the control of the general surgeons, and, after a period of travel which included Liverpool and Scandinavia, W. H. Trethowan was elected as the first specialist orthopaedic surgeon in 1913. Blundell Bankart, also a Guy's man, had previously thrown in his lot with the Royal National Orthopaedic Hospital, where after serving as registrar he had been appointed Assistant Surgeon with the duty of acting as substitute in the absence of any one of the five senior surgeons.

In the provinces, at Liverpool, was that unique figure Robert Jones, already with a world-wide reputation as shown by his election as President of the Orthopaedic Section of the International Congress of Medicine which met in London in the summer of 1913—a mammoth gathering by the standards of those days. This choice was the cause of heartburnings amongst some of the London orthopaedic surgeons who had resented Robert Jones's invasion of London practice. In their young days Robert Jones and A. H. Tubby had been close collaborators in the literature of orthopaedics—their monograph on *The Surgery of Paralyses* was an outstanding contribution of its time. They had also shared a shoot in Luxembourg, where on occasion they had been joined by Vulpius of Heidelberg, a pioneer in the technique of tendon transplantation. But by 1913 it was evident to the onlooker that a coolness had developed between these two distinguished men who represented British orthopaedics in the world of surgery as a whole. It has been said that whereas history does not repeat itself but historical situations recur, we see once more the fraternisation of orthopaedic surgeons in the pursuit of game when Bryan McFarland and Robert Judet meet together in Luxembourg!

At the Royal Southern Hospital, be it remembered, Robert Jones was for many years by title a general surgeon, but at Heswall and at Baschurch he had the resources of two long-stay orthopaedic institutions.

Birmingham had also long been a centre of orthopaedic practice. The Orthopaedic and Spinal Hospital founded in 1817, which merged with the Woodlands Hospital in 1925, had been staffed in traditional fashion by a succession of general surgeons with varying degrees of interest in orthopaedics. The arrival of Naughton Dunn in 1913, a product of the Liverpool school, gave Birimngham its first true specialist orthopaedic surgeon. Across the Irish Sea, also, classical orthopaedics had been cultivated in a small special hospital in Dublin, the best known exponents of the art at this time being R. L. Swan and W. S. Haughton, who both practised general surgery.

THE FIRST WORLD WAR

It is a chastening thought that but for the impact of the first world war on the surgery of injuries of the locomotor system, the emergence of orthopaedics as an independent surgical speciality covering a wide field, and playing an important role in undergraduate and post-graduate teaching, might have been long delayed. But one thing is certain above all: if there had been no Robert Jones, we, all of us, would not be where we stand to-day.

In retrospect the story of the organisation of the Military Orthopaedic Centres under his leadership, beginning with Alder Hey, followed by Shepherd's Bush—now the Postgraduate Hospital—and ultimately at all the territorial general hospitals in the provinces and Scotland, is one of the glorious chapters in the history of British surgery. But the segregation under Army Council orders of certain categories of injured soldiers to be treated only by a small group of designated orthopaedic specialists, most of them young and unknown, was a revolutionary notion which in the opinion of some of the senior general surgeons of the country was one to be opposed. Robert Jones had thus to face hostility, much of it behind the scenes, but he won the battle by his tolerance and understanding. The Council of the Royal College of Surgeons was almost persuaded to join the opposition, but under the influence of Moynihan, Lynn Thomas and Hey Groves wisely resolved to take no official action.

One of the most contentious matters was the inclusion of peripheral nerve injuries in the list of cases to be transferred to the orthopaedic centres. This subject was remitted for discussion to the Army Consultants' Committee. The Consulting Surgeon to the Eastern Command, in which no orthopaedic centre had been organised, was then that blunt Lancastrian, Colonel T. H. Openshaw of the Royal National Orthopaedic Hospital and the London Hospital, who, when asked by Sir Robert whether he was accustomed to operate on brachial plexus lesions, replied: " Yes, as a general surgeon but not as an orthopaedic surgeon! "

There are few who can enjoy the best of both worlds. But to do justice to his memory, T. H. Openshaw made his contribution to the orthopaedics of war after his own fashion in the initial organisation of Roehampton as a limb-fitting centre. There he was followed by Muirhead Little when the work demanded the full-time supervision of a senior surgeon with a mechanical flair.

FOUNDING OF THE BRITISH ORTHOPAEDIC ASSOCIATION

If the renaissance of orthopaedics in the first world war was a historical event which in the last analysis stemmed from the vision and actions of one man, Robert Jones—a man born at the right epoch and by his early experience uniquely fitted for the task—we do not overlook the contributions of the many inspired by his leadership. It was at this time that the bonds of friendship and understanding between the orthopaedic surgeons of the United States and of this country, so secure and so significant to-day, were first forged. Here again the devotion of one man to a cause was of outstanding importance. Of the part played by Robert Osgood of Boston in the work of the Military Orthopaedic Centres, Sir Robert wrote as follows: " His work during this period was colossal. He not only helped in organising, but he also visited centres all over the country inspecting the work, training the men, settling disputes, changing chaos into harmony. All this was effected with such tact and understanding that a welcome was accorded him everywhere." Before Osgood left us to devote his whole time to the rapidly expanding orthopaedic organisation of the United States Army Medical Corps, he had achieved his heart's desire. He had convinced the senior British orthopaedic surgeons that the time was ripe for the creation of a British Orthopaedic Association. It was Osgood, and Osgood alone, who persuaded Mr Muirhead Little, Sir Robert and Colonel Openshaw to invite a selected list of guests to dine in London as the first step in the launching of the new Association. Colonel Tubby was then in Cairo as Consulting Surgeon to the Army in the Middle East, and Captain, later Colonel, Fairbank was in the Salonica zone.

The dinner at the Café Royal held on November 28, 1917, with the senior host Mr Muirhead Little in the chair, is now a landmark in our history. In addition to the three hosts the following guests were present—I give them their military titles: Lt.-Colonel Harold Stiles, Captain D. M. Aitken, Major R. C. Elmslie, Mr W. H. Trethowan, Captain Naughton Dunn, Captain W. R. Bristow, Mr E. Laming Evans, Mr A. S. B. Bankart, Major E. W. Hey Groves, Captain G. R. Girdlestone, Captain H. Platt, and Major Robert Osgood.

The proceedings on this occasion are recorded in legible script in the first temporary minute book of the Association, until to-day retained in my own archives, but which I now restore to its rightful ownership! I read therein, and without difficulty, that on the invitation of the Chairman, " Major Osgood gave a full description of the constitution and activities of the American Orthopaedic Association and expressed his strong desire that the new body when formed should be closely affiliated to the older body, the two sister associations ultimately forming an International Association." Note the vision in this statement. " He further stated that the present American Journal of Orthopaedic Surgery could be looked upon also as the journal representing the British Orthopaedic Association, and that he felt certain that the cost of production would still be borne by the American Association. In his description of the working of the American Association Osgood laid stress on the importance of three committees—Nomination, Editorial, and Programme Committees."

Before the end of the dinner three temporary working committees under the chairmanship of Mr Muirhead Little had been chosen: 1) A *Membership Committee* to determine which surgeons should be invited to become original members of the new Association; 2) an *Executive Committee* to approve, reject, or add to such membership, and to organise the inaugural meeting; and 3) a *Committee on Constitution and Bye-Laws.* The latter consisted of three people—Colonel Sir Robert Jones, Major E. W. Hey Groves and Captain H. Platt. I quote these names in view of what was to happen soon after.

There can be no doubt that Robert Osgood was the prime mover in the foundation of our Association. Without his intervention the Orthopaedic Sub-Section of the Surgical Section of the Royal Society of Medicine, which had been formed in 1913, might have been regarded as a forum adequate for the needs of the time. Who can tell? We might perhaps have found shelter as a strong group within the Association of Surgeons—the child of Moynihan, friend of Robert Jones. In this connection I would say that the gulf which separates the two great Associations to-day is not good for the future of British surgery.

And so, forty years on, we salute the memory of Robert Osgood as at least *primus inter pares* amongst our Founding Fathers.

At the first meeting of the Nomination Committee in December 1917 seventeen surgeons were selected as the original members for approval by the Executive Committee. There were two notable omissions—the names of E. W. Hey Groves and G. R. Girdlestone, both of whom had attended the Café Royal dinner. The list also contained three new names from Birmingham in addition to that of Naughton Dunn, and one name from Dublin, R. L. Swan.

The Executive Committee met for the first time on January 10, 1918. It was an important occasion. Two of the Birmingham nominations were rejected and three new names were added to the list—W. S. Haughton of Dublin, who used to sing to us at the annual dinners of the Association; Theodore Armour; and T. P. McMurray of Liverpool. It was then learned that R. L. Swan of Dublin, whose name had appeared on the first list of the Nomination Committee, had died more than a year before: the intelligence service of the embryo Association was evidently a primitive affair. But even in modern times, in the selection of foreign members, I have felt that on occasion a similar degree of myopia has been manifest.

The omission of the name of E. W. Hey Groves from the list of original members presented an embarrassing situation. I had already been in correspondence with him about the constitution and bye-laws to be adopted by the Association, which it was agreed should be based on the pattern of the constitution of the American Orthopaedic Association. It was true that Hey Groves in his civilian capacity was a general surgeon, but he was recognised in the surgical world as a pioneer in the technique of osteosynthesis, and had loyally placed himself under the direction of Sir Robert by accepting charge of the Orthopaedic Section of the Territorial General Hospital based on Bristol. Looking back over the years I still find it difficult to understand and to condone the illogical " purist " attitude then adopted by men who were to become my close friends in later years. For Girdlestone, a younger man and indeed a recruit to orthopaedics only during the war—this was true also of Rowley Bristow who made the grade without comment—the temporary hold-up was of little consequence. In due course Girdlestone presented a thesis which the Association could demand from candidates during those early years, and became a member in the summer of 1918.

I have looked through the minutes of the various committees for the years 1918–21, the period of my honorary secretaryship, and I cannot find any reference to the belated invitation to Hey Groves to become an original member. Our archives show that he was invited to attend the annual meeting in Edinburgh in June 1920 as a visitor, where he read a paper on bone grafting; that he spoke at the Executive Session of the Annual Meeting in October 1923 (he must by then have been admitted to membership); that he was put on the Editorial Committee in 1925; and finally that he was nominated as president of the Association for the years 1928–29. It was a source of deep satisfaction to me, and I know it was to Sir Robert, that the Association had seen fit to make full amends to this distinguished general surgeon who did so much to advance the art and science of orthopaedic surgery. That the young Association could act with imagination, when so inclined, is shown by the addition of two names to the original member list at a meeting of the Nomination Committee on February 28, 1918—Arthur Rocyn Jones and Stephen Alwyn Smith, whose early death was a great loss to British orthopaedics.

INAUGURAL MEETING OF THE ASSOCIATION

I shall say little of the Inaugural Meeting of the Association, which took place at Queen Mary's Convalescent Auxiliary Hospital, Roehampton House, on February 2, 1918. It was attended by twelve of the original members, with Robert Osgood as a guest. Sir Robert, detained by War Office business, sent a telegram expressing his regret for absence and wishing the Association every success. The Association was founded by formal resolution with an original membership of eighteen surgeons. Mr Muirhead Little was chosen as the first president, with Sir Robert as vice-president; a draft constitution and bye-laws were adopted; and an imposing list of honorary and corresponding members was compiled. There followed a demonstration of amputees and prostheses, a visit to the workshops, and, in the afternoon, a lively discussion on " nerve bulbs in amputation stumps "—a topic of great importance at that time. The Association was thus launched with a background of classical orthopaedics—the care of the limbless. The time has now come to bring this problem back to its old home.

THE EARLY YEARS OF THE ASSOCIATION

In the first few years of the life of the Association, the minutes of the various committees and the records of the proceedings at the annual meetings reveal a preoccupation with the problem of sharing a journal with the American Orthopaedic Association, and with the growth of orthopaedic schemes fostered by social legislation. At first the affairs of the Journal seemed simple enough. There was a three-year agreement to provide twelve British papers a year and an annual subscription list equal to the numbers of the Association. By November 1918 there were thirty-three British subscribers, twenty-four members and nine outsiders, the annual subscription then being seventeen shillings! Three years later, despite criticisms of the arrangements, the agreement was renewed, and it is a veritable tribute to the strength of the bonds of Anglo-American friendship that the partnership has survived to this day through many vicissitudes. Both Associations are deeply indebted to two great American Editors—Elliott Gray Brackett and William A. Rogers.

With the election of Sir Robert as president in 1920, an office which he held for five years, the Association expanded steadily and British orthopaedics continued to gain in stature from his world-wide influence. His election as Emeritus President was a graceful gesture.

In the years between the wars the field of orthopaedics was to those of us then young an expanding universe, and we fought the battle for the control of fractures with gusto. Rowley Bristow was the spearhead of the attack on the ideological barricades of the London teaching hospitals. Our opponents often accused us of adopting the attitude of the German philosopher Nietzche—" that a good fight sanctifies a cause."

The advent of the second world war found the Association fully prepared to apply the lessons remembered from the days of 1914–18 and the fruitful years which immediately followed. It was ready also to take full advantage of the new knowledge and techniques which the age of antibiotics and resuscitation offered to the surgeon.

ENVOI

Since the second world war we have seen our Association grow to its present astounding size, with its annual meetings international congresses in miniature; and, with the arrival of the National Health Service, the distribution of young orthopaedic surgeons throughout the length and breadth of the nation. I think there is no doubt that, for some time after the first world war, orthopaedic surgeons were the darlings of the gods. But now the limelight has shifted to others—amongst them the plastic surgeon and the cardiac surgeon—and we are finding that the field of orthopaedics is a contracting universe. This is due on the one hand to the inevitable decline in the incidence of certain crippling affections, and on the other to the erosion of our field by the growth of new specialities, often narrow and easily acquired.

There are also tensions within our ranks, as seen by a lack of understanding between the exponents of the idea of the accident service as an independent entity, and the exponents of the continued supremacy of mixed orthopaedics. This I believe to be a domestic issue, and one which surely can be settled within our Guild in the spirit of Robert Jones, whose definition of the field of orthopaedics is still our guiding star: " The treatment by manipulation, operation, re-education and rehabilitation of the injuries and diseases of the locomotor system." So much for our therapeutic field as craftsmen.

But we have an inescapable duty to advance knowledge by research, both fundamental and applied. To fulfil this obligation I believe that we must bring orthopaedic surgery back into the field of surgery as a whole, and come closer to the basic medical sciences. I would like to see the Association take the first positive lead in opposing the premature specialisation which seems to be leading to an irreversible fragmentation of the art and science of surgery. Such an action would be a great stimulus to those Surgical Colleges throughout the world who are deeply concerned with the education and training of the surgeon of the future.

I salute the Association on its fortieth anniversary. It has done much for me throughout those years—not least to-day—and I am confident that it will continue to be an abiding inspiration to generations of orthopaedic surgeons yet to come.

STUDIES ON THE PATHOLOGY OF LOW BACK PAIN

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It is now about thirty years since Schmorl (1929) described structural changes in intervertebral discs and in intervertebral bodies observed at necropsy. Disc surgery during the last twenty-five years has shown that there is a high incidence of disc ruptures in patients with low back pain and sciatica, and there is a wide belief that low back pain originates in the discs. Although it can be well understood and accepted that structural disc changes may lead to circumscribed local disc sequestrations, causing mechanical pressure on lumbar nerve roots, the underlying mechanism of low back pain is still not known.

Since 1940 a number of investigations have been done in Sweden in order to correlate the clinical picture of low back pain with structural changes in lumbar intervertebral discs.

CLINICAL FEATURES OF LOW BACK PAIN

The clinical diagnosis of " low back pain " covers a number of different symptoms. Mostly it is comprised of pains and tiredness in the lumbar area of the back. Although many diseases can give rise to referred pain in the back, most of those who complain of back pain are young or middle-aged people with no abnormality elsewhere in the body than in the spine or the surrounding tissues.

In order to establish a basis for further discussions 15,000 cases of backache were classified (Friberg and Hirsch 1946). All were in patients examined at the orthopaedic department of the Medical School in Stockholm from 1936 to 1946, and 9,500 of the patients had been radiographed. It was found that the symptoms began in the late twenties, and that the highest incidence was between the ages of thirty to fifty years. The incidence was equal in men and women. On plain radiography roughly half the patients showed narrowed interspaces, bony sclerosis and osteophytes, indicating disc degeneration in the lumbar spine. Forty-eight per cent of these degenerative changes occurred in the fourth lumbar disc and in 75 per cent either the fourth or the fifth disc was involved. In 15 per cent instability between the lower lumbar vertebrae was the only radiographic sign of disc change.

Seventy-four per cent of the men were engaged in physical work. This proportion corresponds roughly with the country's proportion of labourers. There was no evidence that heavy physical work was the direct cause of disc changes.

In order to estimate the incidence of low back pain in Sweden, Hult (1954) made an extensive study in different areas of the country among men of different professions. About 2,000 people were questioned, examined and radiographed. The incidence of low back pain was 65 per cent. There was no significant difference in the incidence among heavy manual labourers and other groups, but it was found that when those employed in physical work were affected they had to stay off work much longer.

Of those with acute pain 20 per cent blamed an injury. Another 20 per cent stated that the pain began while they were carrying heavy objects or were subjected to some kind of mechanical stress. The remaining 60 per cent were unable to ascribe any cause.

In addition to these studies Friberg and Hirsch (*loc. cit.*) examined twenty-five patients between twenty-five and forty years of age with acute back pain, with regard to involvement of

other parts of the body. In none of these patients was anything found that could be said to be a causative factor.

ANATOMICAL STUDIES OF LUMBAR DISCS

Since clinical experience suggested that lumbar intervertebral discs might develop structural changes that would account for low back pain it became obvious that we would have to re-examine the anatomical appearance of the discs. For this work we have since 1946 collected hundreds of necropsy specimens of the spinal column from persons of all ages. Most of the studies have been on subjects aged between twenty and fifty years. The lumbar spine was dissected out with the sacrum within a few hours of death and fixed in a vice to permit radiographic studies in flexion and extension in the fresh state. After fixation in formalin the intervertebral discs were cut through horizontally and examined grossly and microscopically. It was concluded (Friberg and Hirsch 1949) that the nucleus shows regressive changes quite early. With increasing age the water content in the nucleus decreases, the fibrous structure increases, and the delimitation from the annulus becomes less marked.

It was difficult to decide when a disc should be classified as pathological. It became obvious that the term degeneration as a clinically reliable statement could be accepted only when ruptures were seen in the annulus. The type and localisation of the ruptures are different at different levels of the lumbar spine. In the two lowest discs the degenerative changes occur mainly posteriorly. They have a characteristic configuration. The rupture of the annular fibres often starts from the inner side of the annulus and extends from the centre of the disc posteriorly or postero-laterally, being surrounded by smaller ruptures undermining the whole posterior area of the disc. When enough collagen bundles are broken the fibrous construction of the annulus loses its concentric shape, some fibres retract and tissue from central parts of the disc seems to squeeze or replace annulus areas. Parts of the disc then become necrotic, disintegrate, and become partly replaced by connective tissue, but the whole disc is never totally changed. Even in completely degenerate discs there are always remnants left of the former structure.

Among the 500 discs first examined eleven prolapses were found, all in the two lowest interspaces. The discs all showed the same structural changes that were found in other examples of disc degeneration. It thus became clear that a prolapse is a part of the general degeneration of a disc.

Comparison of the degenerative changes in discs with the radiographic appearance showed that a normal radiograph may be consistent with considerable degenerative changes. When on the other hand a radiograph showed a narrowed interspace, sclerosis or osteophytes, the corresponding disc was severely damaged.

After the age of fifty, structural changes are increasingly more common, as are radiographic signs of degeneration, whereas from a clinical point of view the frequency of backache is decreasing. If, therefore, pathological changes in the discs are the cause of low back pain, not all structural changes may give rise to pain. From the macroscopic appearance of the discs it seems clear that it is during the early stages of deterioration, when the discs still have a certain amount of function, that they may cause trouble. When the discs are completely destroyed there is no longer any movement between the vertebrae, and that area of the spine is stable and does not seem to cause pain.

HISTOLOGICAL CHANGES

All the lumbar disc specimens were examined microscopically. Some of them were also studied with the electron microscope (Hirsch, Paulson, Sylvén and Snellman 1952). In the nucleus there is very little structure to be seen with the microscope. The cells are few and other structures are covered by intercellular substances.

In the lower discs fissures and ruptures occur early, beginning mostly at the border between the nucleus and the cartilaginous plates and extending towards the centre of the nucleus. The nucleus is becoming more compact, with diminished stainability, the collagenous structure being visible. These dry necrotic areas can often be seen as early as the third decade.

Under the electron microscope the nucleus in children and young persons shows numerous collagen fibres running in all directions. It is a porous system, the space between the fibres varying. The collagen fibres have the same appearance as in other connective tissues, but they are surrounded by chondromucoid elements, probably chondroitin-sulphuric acids. By fermentative treatment of the specimens the chondroitin-sulphuric components could be eliminated, whereby purified collagen fibres could be seen. In specimens from elderly persons many of the nuclear fibres were uncovered, illustrating structural changes down to the molecular level. It is thus obvious that the nucleus is not a watery gel but is composed of highly organised material.

The annulus is known as a structure where dense fibres are running in different directions. The fibres are grouped in bundles. Some extend from one cartilaginous plate to the other, and some cross from vertebra to vertebra. They take an oblique course, the construction of which we were not able to record.

In the electron microscope the collagen fibres appeared as true collagen structures to which chondromucoid material was attached, although less than in the nucleus. The bundles were twisted and kept together by thin structural elements of chondroitin nature.

As early as twenty years of age the annular fibres seemed to loosen up. Areas were found where the structure was no longer so compact. In these places the stainability changed, indicating biochemical disorder. In the middle of the third decade histochemical as well as structural changes were common in the lower lumbar discs.

Both in front of and behind the annular fibres the long ligaments are to be seen. In man these elements were thin connective tissues. There is a discussion among many investigators whether and how these ligaments are attached to the outer border of the discs. It was our impression that they were closely connected to the annulus and thus took a definite part in the function of the disc. There was a marked difference in the metachromatic reaction. The smaller chondromucoid content of the ligaments suggested that they might be less elastic than the annulus. Structural changes in the annulus might therefore mechanically affect the close relationship between the two anatomical elements.

When ruptures in the annular fibres occurred close to the outer border of the disc a connective tissue reaction occurred in the annulus area. Vessels grew in from the long ligaments, and in the lower lumbar discs from the posterior ligament. These foreign elements appeared as vascular granulation tissue. Our specimens were reviewed to determine the frequency of granulation tissue reactions at different disc levels at different ages. It was found that in the lower lumbar discs the ingrowth of vessels into the posterior part of the disc was common between the ages of thirty and fifty—that is, when low back pain shows the highest incidence. Hirsch and Schajowicz (1952) believed that although nerve elements were not known to be present in discs it might well be possible that they could enter together with the vessels into the annulus. If so, a granulation tissue reaction might explain why some discs became sensitive to stress and painful. Nevertheless every method used failed to demonstrate the presence of nerve fibres.

My present impression is that a connective tissue reaction is a part of the phenomenon of advanced ruptures through the annulus in young adults, when backache is common. So long as the tear stays within the annulus healing cannot occur because of the lack of vascular supply. When an area where repair is possible is reached an attempt is made. The granulation tissue becomes converted into a scar, which is often found in disc lesions in the elderly. The same reaction is found in older people in the upper lumbar region, where low back pain is less frequent.

PHYSIOLOGICAL AND BIOCHEMICAL STUDIES

In 1950, when the data now presented were discussed, it could be stated from the clinical, anatomical and microscopical investigations that mechanical stress factors alone might not be the underlying mechanism for the deterioration of lumbar discs. Since intervertebral discs from about the age of fifteen have no vascular supply they might become more sensitive to metabolic disturbances than other connective tissues. It was thought that biochemical analyses might add some information about the disintegration during early youth in an avascular tissue. These studies were made by Hirsch, Paulson, Sylvén and Snellman (1952).

First the diffusion rate of various substances through the nucleus was recorded. Fresh necropsy specimens were placed in specially made covers, and the diffusion rates were calculated by means of interferometric light microscope. It was found that the rate was low and that only molecules of a certain shape were able to enter. It was supposed that the nucleus must be very sensitive to metabolic disturbances.

The chemical components of the nucleus were investigated and found to be protein, polysaccharides and water. The relationship between these elements was then studied at different ages. It could be confirmed that with increasing age the water content decreased. It was also found that with increasing age the protein component in the nucleus increased, whereas the mucopolysaccharides decreased or remained constant. It seemed to us that the change in the water content was because the structural elements were undergoing a decrease in water-binding capacity during ageing. The relationship between protein and mucopolysaccharides might explain this.

Metabolic disorders are shown already at the age of twenty and increase with ageing. This indicates a change in the mechanical state of intervertebral discs.

COMPARATIVE STUDIES ON DISC DEGENERATION IN ANIMALS AND MAN

It is often considered that backache is due to posture, and that mechanical factors in human beings will put much greater stress on the lower lumbar area than elsewhere. It is also supposed that when a spine is acting in the wrong way or if a person is forced to work in a bad position his discs will suffer. Anatomical variations in the construction of the spine, such as congenital anomalies, are also considered to increase the liability to back trouble.

Although some of these suggestions seem to be valid our clinical observations did not show a considerable increase in anatomical variations in those with backache; nor did bad posture or heavy work seem to be significantly more frequent.

It is believed that dogs and cows suffer backache and that degenerative changes in their discs are common. In Sweden Hansen (1952) found that, in some breeds of dog—such as dachshunds, pekinese and bulldogs—belonging to the chondrodystrophoid types, degeneration and prolapse of the discs are common. The structural changes are very like those in man. The incidence of disc degeneration is high in the middle region and somewhat less in the low thoracic region. When prolapse occurs it may give rise to paraplegia. There may be a profuse connective-tissue reaction under the posterior longitudinal ligaments, the tissue being very like what has been described above as granulation-tissue reaction.

In cows the lumbo-sacral junction is the most mobile part of the spine. It would therefore be expected that if mechanical factors were to affect the discs the structural changes would occur in that area. According to Hansen this is in fact so. In cows the greatest tear is in the posterior ligament, and ruptures and disintegration as well as minor fractures in the posterior edges of the vertebrae occur very early.

If these observations on animals are compared with what is known in men it seems that degeneration in the low lumbar region is the result of mechanical stress.

MECHANICAL FUNCTION OF LUMBAR DISCS

Although it became more and more obvious that avascular necrosis followed by mechanical stress was the main cause of early degenerative changes in the lower lumbar area, it was still not understood how this would produce pain. Nerve elements do not exist inside a disc, but they are known to be present in the posterior longitudinal ligament. Structural changes and ruptures in the annulus might weaken the posterior part of a disc, and thereafter abnormal movement between the vertebrae and bulging of the posterior area of the disc might stress the sensitive posterior ligament.

It was suspected that if in patients with backache the pressure inside a disc could be raised it would cause pain. We therefore undertook a series of disc puncture experiments. A lumbar puncture needle was introduced transdurally into the posterior area of a lumbar disc under radiographic control. Normal saline was injected. In some discs less than one millilitre could be instilled even with strong pressure on the syringe. In these cases the patient felt no pain. In other discs more than one millilitre could be injected easily, and pain occurred when the pressure was raised. In these cases the patient stated that it was the same pain that he usually had when his backache was present. When the pressure was released the pain disappeared immediately if very little procaine was injected.

It was supposed that the pressure inside the disc had produced stress on the posterior area of the annulus and caused a deformation which affected the posterior ligament with its sensitive nerve elements.

Lindblom (1950), investigating disc puncture and nucleography with a water-soluble contrast medium, found that those discs where pain occurred were really degenerated discs with ruptures of the annulus.

Everything now seemed clear. Degenerated discs could under certain circumstances not tolerate some extra stress that caused pain. If the posterior area was anaesthetised the nerve elements in the posterior ligaments became insensitive and the pain disappeared.

Hirsch and Nachemson (1954) later studied the mechanical tolerance of lumbar discs under normal and pathological conditions. Pressure machines were built and measuring instruments were installed which would allow us to record movements and deformations down to thousandths of a millimetre. Using displacement pick-ups and strain gauges connected to oscillographs incorporating high speed cameras, almost any small movement occurring during a hundredth of a second could be seen.

When a disc with its vertebrae below and above is subjected to pressure it deforms according to a typical curve. The amount of compression is dependent on how much pressure is applied. Most discs will take 300 to 400 kilograms before the breaking point is reached. With 100 kilograms load the total compression in a normal disc is about one millimetre.

If a load is maintained for several minutes a typical time-compression curve will occur where the disc after having reached its main deformation after half a minute tends towards a maximum.

The amount of bulging that occurs in the annulus while the disc is under pressure is very little in normal discs—about 0·5 millimetre for a 100-kilogram load. Degenerated discs deform more; but though the figures are about 100 per cent higher, the amount in millimetres is still not high. A disc with ruptured annular fibres subjected to a load of 100 kilograms would bulge only about one millimetre, which could not be accepted as giving rise to backache.

If a lumbar interspace is subjected to fast-acting shocks from loads falling on the specimen the disc starts to vibrate. These vibrations will die out rapidly during less than a second. Mild or moderate degenerative changes have very little influence on the vibration curves. If an intervertebral disc is loaded, and thus somewhat compressed, the amplitude of the vibrations will be less.

The lumbar discs act as stabilising shock-absorbing tissue elements. Mild or moderate degenerative changes make them less efficient even though their mechanical response does not differ greatly from what can be considered normal.

On both normal and degenerated discs from fresh necropsy specimens, disc punctures were performed while the discs were surrounded by measuring instruments. In neither of these specimens did deformations occur that could be seen on the recording instruments.

These mechanical studies seem to indicate that pain does not occur from the disc because it presses on the posterior ligament.

MECHANISM OF PAIN

In order to explain mechanically the pain mechanism we will have to reconsider the posterior structure of a disc. The ligament may be considered as a tape on a rubber tube. If the tube is expanding there may be considerable stress at the junction of the two elements even though the tube has not moved very much. This is because of differences in their physical properties. Normally, if a disc is subjected to mechanical forces there will be a reaction through the entire disc. The nucleus will distribute pressure towards different parts of the annulus, and the annulus will become compressed because its fibres will stretch and bulge. If the nucleus has become dense and necrotic, and has lost part of its water content, it is no longer able to act as a pressure distributor, the entire stress being transferred to the annulus. This might explain why the annulus ruptures. If part of the annulus is out of action considerable stress may occur between the annulus and the ligaments.

This mechanical explanation makes it possible to understand why severely degenerated discs do not cause any pain. If the disc has lost its function, its elastic structure being largely replaced by the ingrowth of connective tissues, the interspace is stable and no such stress actions can occur between the long ligament or any surrounding sensitive tissues and the remnants of the disc.

In 40 per cent of those with acute low back pain it was stated that the onset of the attack started while the patient was under mechanical stress. Our mechanical experiments offer an explanation for this. If a disc is under compression part of its shock-absorbing capacity is used up because the collagenous structure is stretched. There is thus less available when some extra stress suddenly strikes the spine. The tensile strength is exceeded and the breaking point is reached. It was recently shown by Perey (1957) that in young people two things might happen: if the disc is normal the vertebra breaks; if the disc is degenerated the fibres of the annulus rupture.

CONCLUSIONS

Disc degeneration starts as an avascular necrosis. In the lower lumbar area the discs deteriorate early because of mechanical stresses. During certain early periods of degenerative changes a mechanical disorder between the annulus and the posterior longitudinal ligament may cause tiredness and pain. When the disc is completely degenerated and has lost its physical properties backache disappears.

SUGGESTION

Because of the biological appearance of ageing processes in lumbar intervertebral discs, theoretically there might be two ways of eliminating backache. Either we will have to find methods by which discs can recover biologically and we will have to improve the nutritional mechanism, which does not seem to lie within our reach; or we will have to find methods by which the deterioration can rapidly pass the stage at which a mechanical disorder causes pain. Sooner or later a substance may be found by which a degenerated disc could be transformed to dense connective tissue. It might be possible to create a chondrolytic enzyme

that, injected into a disc, would cause a connective tissue reaction. We already know several bacteria in which such enzymes are present. It might be possible in one way or another to make them available.

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LOW BACK PAIN DUE TO ARTERIAL OBSTRUCTION*

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There are enough commonly known causes of backache to torment, as well as to test the skill of, the practising physician. In addition to the more recognised causes, backache from vascular obstruction must be considered. The following observations support this fact.

The term claudication properly means limp, and in some instances there may be no pain but only weakness of the legs with disturbance of gait. " Intermittent claudication " has generally been applied to the cramp-like pain in the calf brought on by exertion and relieved by rest. This symptom, as a rule, is so typical in the lower extremities that when such information is obtained the diagnosis of arterial obstruction may readily be made. Even in the absence of the more frequent discomfort in the legs, such pain may be located in the muscles of the low back and gluteal regions. Because the pain in the low back may be the predominant, or at times the only, symptom of arterial obstruction, the actual etiology may be overlooked and the back pain attributed to some local disease of the musculo-skeletal system.

Such observations have been made before in isolated cases. Homans (1939) stated that the discomfort of peripheral vascular disease could at times simulate " sciatic neuritis." Leriche (1940) described the syndrome that now bears his name, and in a more complete account (Leriche and Morel 1948) he emphasised that thrombotic obliteration of the aortic bifurcation does not necessarily cause a typical cramp-like calf pain, but that more frequently the patient complains of easy fatiguability in the lower extremities. Although none of the four patients that he reported had associated low backache, one had symptoms typical of " sciatica." Leriche mentioned other signs and symptoms, such as impotentia erigendi, pallor of the legs and feet when standing, and global atrophy of both lower extremities, and these symptoms have often been regarded as an essential feature of aortic or iliac obstruction. Subsequent workers (Morel 1943; Kramer, Perilstein and de Medeiros 1958) have found that any or all of these additional signs may be lacking and that the only symptom may be that of pain or weakness in the legs.

Other observers (Ortner and Griswold 1950; Samuels 1950; Goodwin and Petrie 1951; Kekwick, McDonald and Semple 1952; LeFevre, Phalen and deWolfe 1953; deWolfe, LeFevre, Humphries, Shaw and Phalen 1954; and Phalen 1955) have reported cases of cramp-like suffering in the low back associated with similar pain in the gluteal muscles and in the muscles of the thighs and calves after exertion. Pain localised exclusively in the back, however, has not received adequate attention.

The present study was prompted by the investigation of several patients with aorto-iliac obstruction who appeared with low back pain as the initial symptom. Sixty patients, fifty-two men and eight women, were seen at the Johns Hopkins Hospital in a period of six and a quarter years, between June 1952 and September 1958. The diagnosis of aorto-iliac obstruction was proven in each case either by aortograph, operation, or both. Analysis of these cases showed that thirteen of the sixty patients had low back pain, with or without " sciatica," as a prominent symptom. In two instances the low back pain was attributed to a previous injury to the back, and in one other instance to a urinary tract infection. Ten patients had been

* Paper read at the fortieth annual meeting of the British Orthopaedic Association at Oxford, England, in October 1958.

treated for neuromuscular disease of the back; in one of these a ruptured intervertebral disc had been removed with relief of symptoms eight years before the vascular symptoms developed. In the others, the orthopaedic treatment was not so clearly indicated, if at all.

There were two negative explorations for ruptured intervertebral discs, and two spinal fusions. In one of the latter cases an exploration of the hip was carried out, all without relief of the back pain or the " sciatica."

Of the thirteen patients with low back pain, four had lumbar sympathectomy performed with some relief of back pain, and another died after an extensive endarterectomy of the entire abdominal aorta. This left eight patients available for follow-up study who had had their circulation re-established by endarterectomy or some type of arterial graft. Six of these eight patients, or 75 per cent, had relief of their low back symptoms after re-establishment of the circulation. In two patients no relief of back pain was obtained from the operation. One of these patients had clinical and radiological evidence of degenerative discogenic disease, for which he had had previous non-operative treatment. The following case histories illustrate these points.

CASE REPORTS

Case 1—A woman of forty-seven complained of low back and sacral pain of eleven years' duration, which followed walking with crutches after a fracture of the left femur. Her gait returned to normal, but the back pain persisted. It was believed that her back pain was psychogenic, and she had had prolonged psychiatric treatment, including a series of shock treatments. Although her functional condition improved, the back pain became progressively worse and incapacitating. She consulted several orthopaedic surgeons during this period, and was given many of the usual forms of routine treatment, such as back supports, physiotherapy, and a bed board. She had been admitted to another hospital two years before consulting us, at which time a myelograph had been performed with negative results. She then received another long course of physiotherapy, including postural exercises. Eighteen months before we first saw her, she noticed that the low back pain became worse after walking a short distance. Soon thereafter, for the first time, she began to notice numbness and coldness of the feet and legs. The back pain was not aggravated by activities requiring bending, stooping, lifting, or twisting, and the pain in the back and legs was not increased by coughing, sneezing or defaecation. The general orthopaedic examination showed no abnormality except for the residual effects of the fracture of the left femur. Neurological examination was normal. Examination of the back was also within normal limits, including straight leg raising and rectus femoris tests. Both feet were cold and we were unable to palpate the femoral, popliteal, the dorsalis pedis, or the posterior tibial pulses on either side. Radiographs of the lumbar spine and sacrum showed mild hypertrophic arthritis, but considerable calcification of the abdominal aorta was observed. Aortography showed occlusion of the distal aorta and common iliac arteries. An aorto-iliac endarterectomy was performed with the establishment of moderate pulsations in the vessels of the legs, and she has subsequently been free from symptoms in the back and extremities.

Case 2—A woman of forty-five had sought advice fifteen years before on account of low back pain which had come on after childbirth at the age of twenty. At that time examination had shown a " sway " back with scoliosis. Postural low back strain was diagnosed and she was given a back support, a series of postural exercises, and a lift on one of her heels to level the pelvis. She obtained considerable relief from these measures. She had then been well for nearly fifteen years, when low back pain again developed and progressively increased. When we questioned her it was revealed that in addition to the back pain she also had sacral, gluteal and groin pain, aggravated by walking short distances. Other than the old postural defect, nothing significant was found on examination of the back. The right femoral pulse was not palpable, and no pulse could be felt in either foot. An aortograph revealed obstruction

of the terminal part of the aorta and both common iliac arteries. Endarterectomy was performed. Recent follow-up indicated that the back pain has disappeared.

Case 3—A man of forty-six had first noticed pain in the right hip while engaging in athletics fifteen years before. The pain became increasingly severe in the following three years. Later, he noticed that playing nine holes of golf aggravated the hip pain, so that he was forced to give up the game. Two years before we saw him he found himself unable to walk more than a short distance because of incapacitating low back pain. At another hospital a spinal fusion had been performed without relief of his symptoms; later, the right hip was surgically explored but nothing abnormal was discovered. Later, when the true nature of the trouble was suspected he was admitted to the Johns Hopkins Hospital, where an aortograph showed aorto-iliac obstruction. At operation the diseased artery was resected and a homograft inserted. Follow-up showed no further low back pain, but he still had mild pain in the right buttock after walking.

DISCUSSION

The diagnosis of low back pain from arterial insufficiency is easily made when other symptoms are present, such as the typical cramp-like pain in the calf on exercise, fatigue on walking, numbness and tingling of the legs, coldness of the extremities, or impotence. However, since such symptoms are frequently not seen early in the course of the disease, it is important to consider carefully the patient's description of the pain. With intrinsic disease of the back itself, stress on the back such as in bending, lifting, stooping and twisting may cause the pain to appear or aggravate it while these movements are being performed. This is usually as severe on the first such movement as on subsequent ones. On the other hand, in back pain from arterial obstruction the activity must be repeated before the pain appears. Repeated activity causes a muscle to outstrip its blood supply, thereby inducing pain or weakness because of its inadequate circulation. Therefore, an important clue may be obtained by merely asking the patient what brings on the pain and what he does about it. Characteristically, he states that it disappears after several minutes of rest, but, when activity is resumed this effort brings on a similar episode. The site of the obstruction can sometimes be deduced from the character of the pain. Pain in the low back itself is often associated with obstruction of the terminal part of the aorta. Occlusion of the common iliac artery is characteristically associated with pain in the buttock, but this buttock pain may also appear with obstruction of the internal iliac [hypogastric] artery alone. Such pain in the back or buttock may or may not be associated with pain in the thigh or calf.

Presumptive diagnosis of thrombosis of the lower part of the aorta or of the iliac vessels, alone or together, is aided by the finding of calcification in these vessels on the plain radiographs of the abdomen or spine. An aortograph may be indicated, to confirm the obstruction and to demonstrate its precise site. The diminution or absence of the femoral and distal pedal pulses is the most consistent confirmatory finding, however, and this is the simplest and clearest aid in the diagnosis of aorto-iliac obstruction.

SUMMARY AND CONCLUSIONS

A considerable proportion of patients with thrombosis of the aorta or its bifurcations exhibit low back pain either alone or in conjunction with other symptoms of this disease. Arterial obstruction should be considered in every patient presenting himself with low back pain. The importance of the history in making this diagnosis cannot be overemphasised. Back or leg pain, or both, coming on after exertion should suggest the diagnosis even in the absence of the other well recognised symptoms of arterial insufficiency. Therefore, to affirm or deny this suspicion, it is essential that palpation of the femoral and peripheral pulses be made a routine and integral part of every orthopaedic examination in patients complaining of low back pain. When pulses are not palpable or are diminished, and in the absence of other

clear musculo-skeletal disease, consideration should be given to further and more specific diagnostic procedures, such as aortography. Only in this way can an occasional baffling and elusive case of troublesome backache be fully understood and the appropriate treatment instituted.

The investigations and the development of arterial surgery was aided by grant H–226 of the National Heart Institute, United States Public Health Service.

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A METHOD OF SPINAL FUSION

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The incidence of failure in spinal fusion is still too high (Barr 1951). It has been stated that if the operation could be undertaken with little or no danger from shock, subsequent thrombosis and embolism, and if it would offer a high prospect of firm union with a short period of bed rest, then a larger proportion of patients would be grafted (Young 1953). Spinal fusion was the subject of an editorial (Scott 1953) in which the need was stressed for a technique in which it would not be necessary to remove bone from other sites or to keep the patients in bed for a long time after operation.

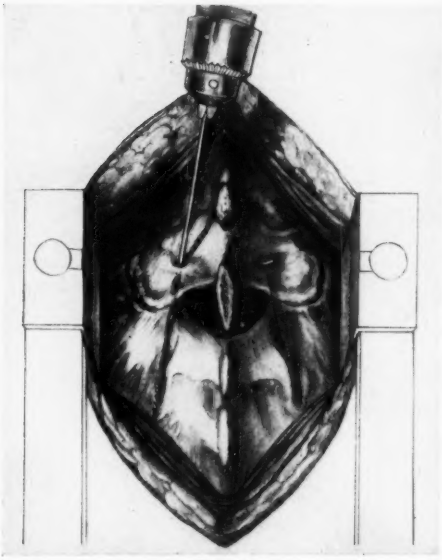

FIG. 1

All soft tissue has been removed out to, and including, the lateral articulations. The guide pin, in practice, is withdrawn after penetrating the cor ex of the ala. The obliquely placed screws avoid the nerve roots.

King (1948) described internal fixation by the use of screws. Short screws were placed almost transversely across the lateral articulations. A high incidence of failure from this method was reported by Thompson and Ralston (1949). Bosworth (1957) stated that screw fixation did not prove to be of value compared to the difficulties encountered, and he mentioned the adverse psychological effect associated with their use.

The principle of internal fixation by screws is sound. Such fixation, however, is only temporary because the screws will loosen (Watson-Jones 1952). Careful preparation of the fusion area and the use of cancellous bone shortens the time needed to obtain fusion. Long, well placed screws give the required stability during this period and make the development of a pseudarthrosis unlikely. This paper describes such a procedure which has been used by the writer for the past twelve years (Boucher 1954).

TECHNIQUE OF LUMBO-SACRAL FUSION

A midline incision is made. The soft tissue is completely removed from the spinous processes and laminae of the fifth lumbar vertebra and from the upper part of the body of the sacrum, out to, and including, the capsule of the lumbo-sacral joint. A gauze sponge interposed between the elevator and soft tissue will simplify the stripping of the laminae. Excision of the fatty tissue just lateral to the ligamentum flavum exposes a bowl-like cavity surrounded by bone except on its medial aspect. It is formed superiorly by the lamina of the fifth lumbar vertebra, laterally by the pedicle of the first part of the sacrum, inferiorly by the first sacral lamina which also forms the floor, and medially by the ligamentum flavum. A screw, one and a half to two inches in length, is driven through the lamina of the fifth lumbar

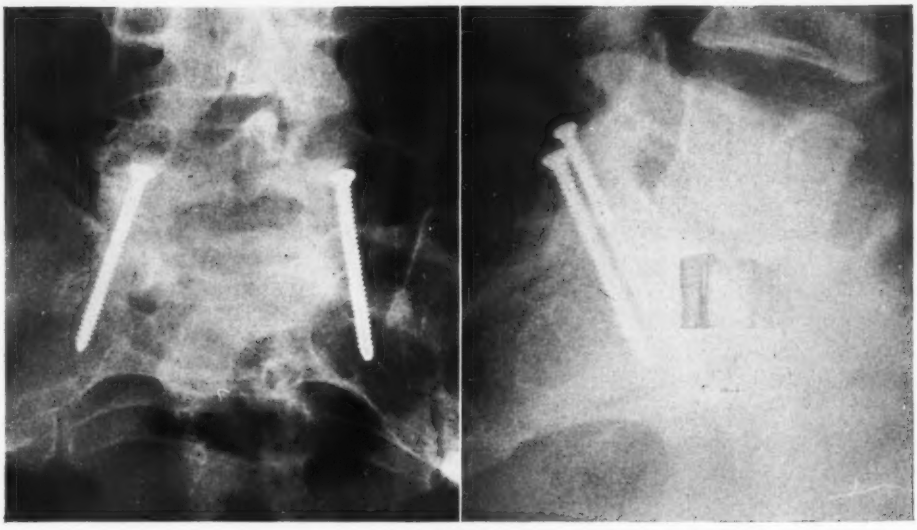

FIG. 2
The long screws traverse almost the full antero-posterior diameter of the alae of the sacrum.

vertebra on each side just medial to the lateral articulation in an antero-inferior and lateral direction (Fig. 1). It enters the ala of the sacrum obliquely, just lateral to the sacral canal, at the base of the superior process, and traverses almost the full antero-posterior diameter of the ala (Fig. 2). The drill hole is made with a long stainless steel pin, three-thirty-secondths of an inch in diameter, introduced by a hand drill, the flexibility of the pin making it possible

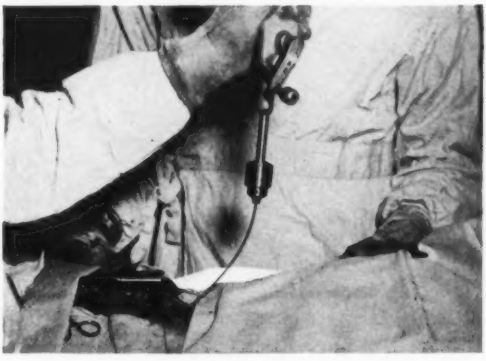

FIG. 3
A flexible stainless steel pin may be bent to obtain the desired direction of the screw. The surgeon faces the head of the patient while drilling.

by firm pressure to bend and guide it in the desired direction. The introduction of this pin is made easy if the surgeon will turn and face the head of the table while drilling (Fig. 3). A self-holding screwdriver may be used to start the screw but should be changed for a plain screwdriver to allow the screw to follow the desired direction. If the spinous process of the fifth lumbar vertebra is in the way of the screwdriver it may be removed. Cancellous bone is

obtained from the posterior superior spine of the ilium which faces the surgeon. It is easily reached by subcutaneous reflection of the original skin incision. The overlying deep fascia is then incised, the roof of the iliac spine is elevated by a broad osteotome and the spongy bone is removed with a large curette. The roof is replaced and snugly sutured to prevent the formation of a superficial haematoma. The cancellous bone obtained is cut up into crumbs with strong scissors. The cortical bone of the bowl-like cavity is elevated by thin, narrow osteotomes, and a little ingenuity will surround this cavity with hinged bleeding flaps (Fig. 4). The presenting posterior margins of the lateral articulations are turned laterally with an osteotome to present further bleeding surfaces, but otherwise the articulations are left intact to preserve stability. The spongy bone is packed firmly into this prepared bed, using the convex side of a broad curved periosteal elevator pressed against a folded gauze sponge. The spinous processes of the first sacral and fifth lumbar vertebrae are turned up and down in an interlocking manner; further bone may be turned up from the first and

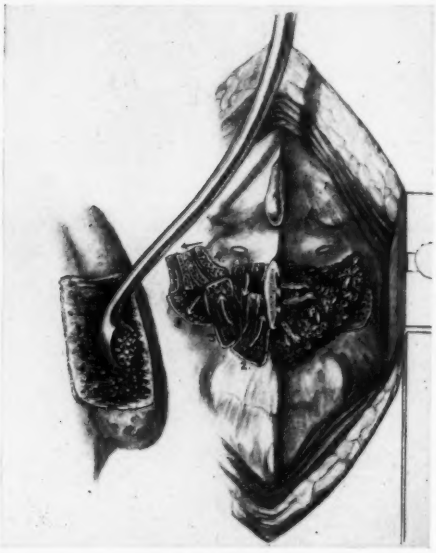

FIG. 4

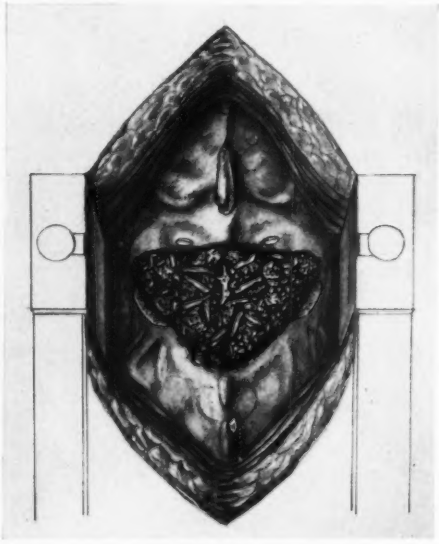

FIG. 5

Figure 4—Preparation of the area for fusion with the use of cancellous bone from the posterior superior iliac spine. Figure 5—The area of bone grafting has been completed.

second sacral laminae and any spare crumbs of bone are added as mortar. When the operation is completed, fixation is firm and the bone mass is usually more than adequate (Fig. 5).

Thorough stripping of the posterior elements of the spine may be associated with brisk bleeding and, as a relatively dry field is most helpful, various measures can be used to obtain this. Epidural anaesthesia without a vasopressor agent and general anaesthesia plus induced hypotension are in common use, or a weak solution of adrenaline may be injected locally. The writer uses whichever method seems best in consultation with the anaesthetist. Blood should be available for immediate use if needed, but frequently the blood loss is so slight that replacement is not necessary.

POST-OPERATIVE MANAGEMENT

The patient is encouraged to move about actively in bed and to get up in a few days, the average stay in hospital being a week or ten days. As fixation is usually sound, no external support of any kind is worn for lumbo-sacral fusions, and it is seldom found necessary to

FIG. 6

Fusion between the fourth and fifth lumbar vertebrae. This placement of screws above the lumbo-sacral level seems to offer satisfactory stability and avoid root irritation. No external support is worn.

support double-level fusions. Spondylolisthesis is the exception. Activity is restricted to walking for twelve to sixteen weeks, with no bending or lifting, the patient being taught to flex knees and hips (as perhaps he should have been doing since childhood and so possibly have escaped the disc lesion). Antero-posterior and lateral bending radiographs are taken about four months after the operation and, if these are satisfactory, rehabilitation of the low back is begun and unrestricted activity is allowed with regard to the general condition of the

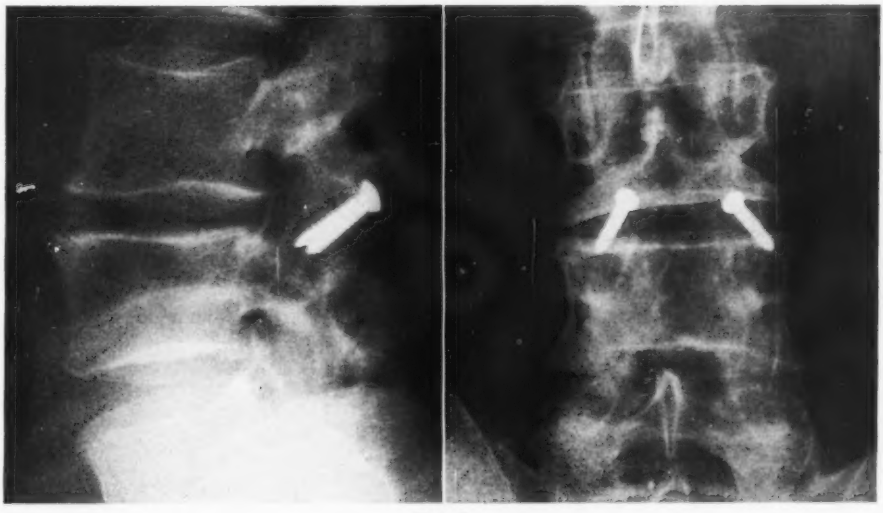

FIG. 7

Fusion between the third and fourth lumbar vertebrae. The screws, though short, engage the root of the pedicle of the fourth lumbar vertebra and fusion was early and sound. No external support was used. Considerably longer screws may safely be used if the technique is as shown in Figure 6.

patient. Occasionally the cancellous bone has not become sufficiently well organised and a few degrees of movement are seen; the patient is then asked to continue being careful with activity, and repeat radiographs a few weeks later will usually show no evidence of movement.

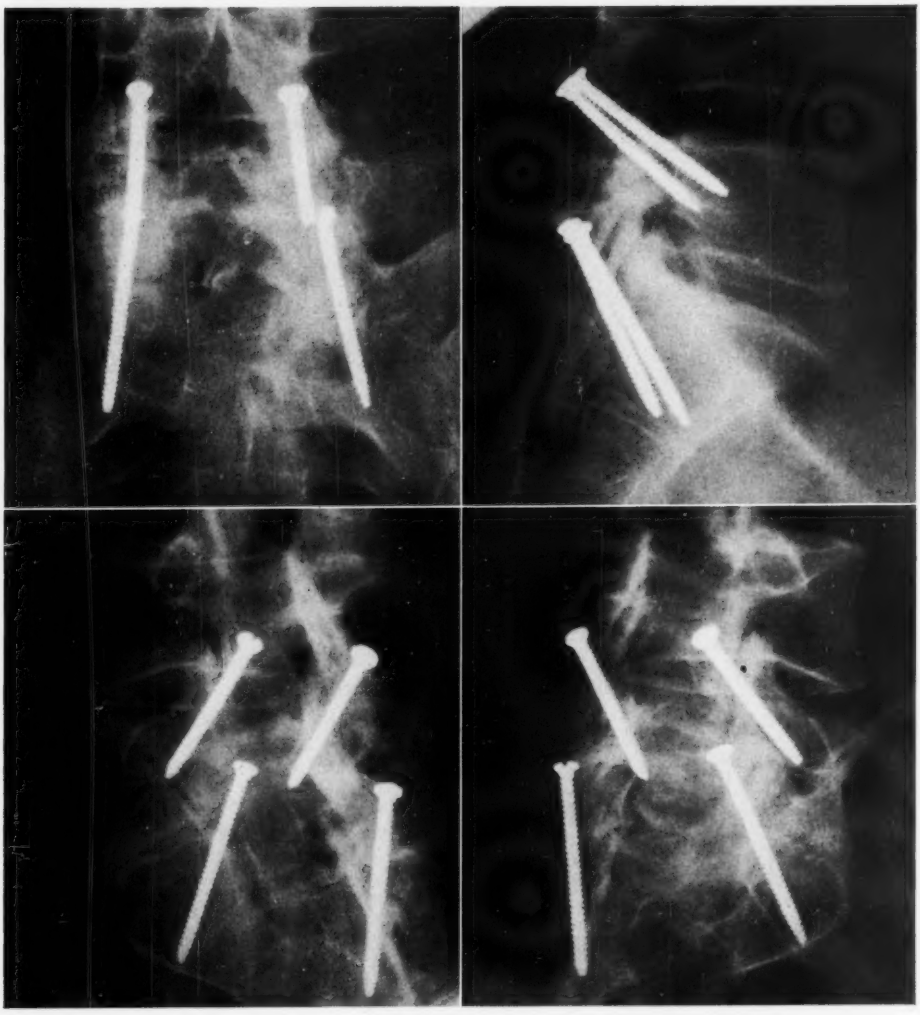

FIG. 8

Fusion at two levels, shown just after operation. This would seem to be a satisfactory placement of the screws, giving the desired stability and avoiding root irritation. No external support will be used.

FUSION AT HIGHER OR MULTIPLE LEVELS

The same technique has been used at the fourth (Fig. 6) and third lumbar levels (Fig. 7) and for multiple fusion operations in the lower lumbar spine (Fig. 8). Above the lumbo-sacral level, the screw is placed so as to pass from the lamina of the vertebra above into the body of the vertebra below, just medial to the root of the pedicle. The drill point, placed well laterally,

will bypass the vertebral canal and enter the upper part of the body of the vertebra below, if directed straight forward and antero-inferiorly at about an angle of 30 degrees or more. The error is usually to allow not enough inferior angulation and thus to engage the very upper part of the body and perhaps the disc (Fig. 9). The obvious reason for trying to keep the screw embedded entirely in the vertebral body is the avoidance of contact with the nerve root below; this complication occurred recently on one occasion when the screw was being directed into the root of the pedicle. This direction had previously been used routinely, without incident and with successful fusion, using somewhat shorter screws; it would probably be best to engage the pedicle because the cortical bone in that region would probably give better screw fixation than the spongy bone of the vertebral body.

FIG. 9

The screws between the fourth and fifth lumbar vertebrae are not directed low enough and barely engage the body of the fifth lumbar vertebra. One screw has broken during fixation.

SPONDYLOLISTHESIS

In spondylolisthesis, the body of the fourth lumbar vertebra is fixed to the body of the fifth by screws, and if the loose posterior element of the latter is not removed it is fixed to the sacrum by short screws. Of the forty-eight patients operated upon for spondylolisthesis, only a few complained of pain radiating to the lower extremities. In all but two this pain was not severe, subsided with rest in bed, and did not return after operation.

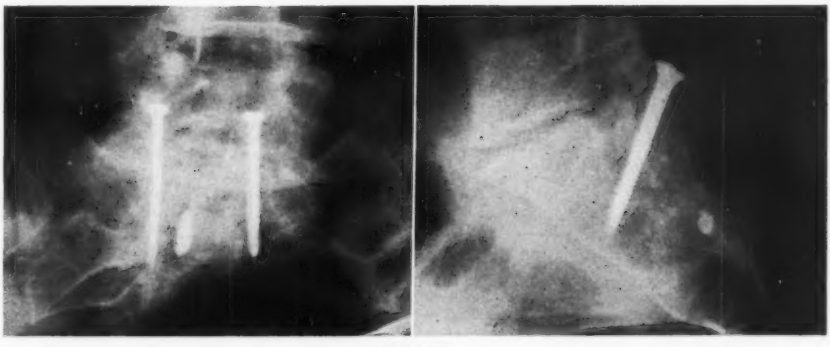

FIG. 10

These screws were placed at a right angle to the vertebral canal rather than obliquely and severe bilateral root irritation was present immediately after the lumbo-sacral fusion. The screws were thought to be responsible. Although signs and symptoms have persisted for several years, the patient refuses further surgery.

In the two mentioned, the loose element was removed and the root exposed. Otherwise, the operative technique is essentially the same and a long single plaster spica extending from just above the ankle to well up on the chest is applied, usually after removal of the sutures.

The patient is kept quiet in bed, except for routine breathing and tension exercises, until the plaster has been applied.

LAMINECTOMY AND SPINAL FUSION

Laminectomy was associated with spinal fusion either as a part of the same operation or as a previous procedure in half of the patients, and did not seem to influence the results unfavourably. Frequently several laminectomies had preceded spinal fusion.

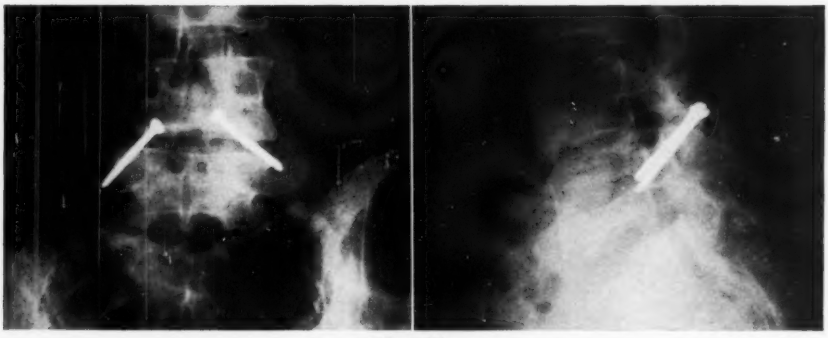

FIG. 11

Fusion at the lumbar 4–5 level produced severe nerve root irritation with sciatic pain and spasm, because the screw (shown on the left) was too oblique.

RESULTS

The usual immediate result of firm screw fixation is a disappearance of the backache. The patient is readily able to distinguish between this and the soreness after surgery, and frequently volunteers, in the early days after operation, that the original backache has

TABLE I

SINGLE LEVEL FUSIONS

Level	Number of operations	Number of known failures
L.S.	130	0
L.4 to L.5	27	0
L.3 to L.4	3	0

TABLE II

MULTIPLE LEVEL FUSIONS

Level	Number of operations	Number of known failures
L.4 to S.1	14	1
L.3 to S.1	1	1

gone and that, for the first time in years, he can lie comfortably in bed. Confidence in the final result develops quickly and the patient frequently has to be warned to restrict his early activity. It was possible to examine clinically all but a very few of the patients several months or years after operation and to obtain bending films in two planes.

This operation has been performed by the author with known results of fusion upon 175 patients with degenerative lesions of the disc in the low lumbar spine and upon forty-eight patients with spondylolisthesis. In the group of degenerative lesions, 130 were at the lumbo-sacral level, twenty-seven at the fourth and three at the third lumbar vertebra. There were fourteen multiple level fusions, thirteen including the fourth lumbar to the first sacral vertebra and one including the third lumbar to the first sacral vertebra. So far as is known, with all available means of testing for non-union, there was no failure in any of the lumbo-sacral fusions or in the single level fusions above the lumbo-sacral region (Table I). Two failures occurred in multiple level fusions (Table II). In one, an attempted fusion from the fourth lumbar to the first sacral vertebra, failure occurred at the fourth lumbar level. Both screws were loose at that level and, on exposure of the lower level, although fusion there was sound, both of those screws were found loose also. Re-fusion of the upper level was successful. In the other patient, a fusion from the third lumbar to the first sacral vertebra had been attempted before, for unknown indications, with failure at all levels. Three subsequent operations were done, two of them by the author, with repeated failure at all levels. On the last occasion, a large autogenous tibial graft was used, held in place by screws and supported by a long single spica from above the ankle to high up on the chest for twenty weeks. Progress radiographs showed that the tibial graft was undergoing absorption, and when the plaster was removed the patient, with an impish grin, bent down with movement at all levels of the spine and touched her toes without difficulty. A persistently positive Kahn test on the blood, unaffected by several heavy courses of penicillin, may have been a factor in the repeated failure of spinal fusion. When seen recently, some nine years since her last operation, she had few complaints of low backache, was still able to bend down and touch the floor and her central nervous system was apparently healthy. This patient had a sense of humour and one felt that her morale rose with each successive failure.

Spondylolisthesis—Of the forty-nine operations done for spondylolisthesis, pseudarthrosis developed in four (Table III). One of these which had failed at the fourth lumbar level was successfully repeated. One rejected the proposal of a second operation, stating that he was sufficiently improved, and the other two agreed to re-fusion but, after a lapse of several years,

TABLE III

SPONDYLOLISTHESIS

Number of operations	Number of known failures
49	4

nothing has been heard from either of them. In one instance a first-degree spondylolisthesis was present between the fourth and fifth lumbar vertebrae due to a unilateral pedicle defect in the former. Fusion of the fourth and fifth lumbar vertebrae only was done, no post-operative support was used and now, some seven months after operation, bending radiographs in two planes show no movement. The patient, with a Workmen's Compensation Board case, is pleased with the result to date and has completed his rehabilitation.

COMPLICATIONS

Deaths—None occurred in the series.

Infection—There were three instances of wound infection. Two were superficial, involving soft tissue only, and one involved bone. This man had been operated on unsuccessfully twice in another country at the lumbo-sacral level. Osteomyelitis on one side of the fusion area

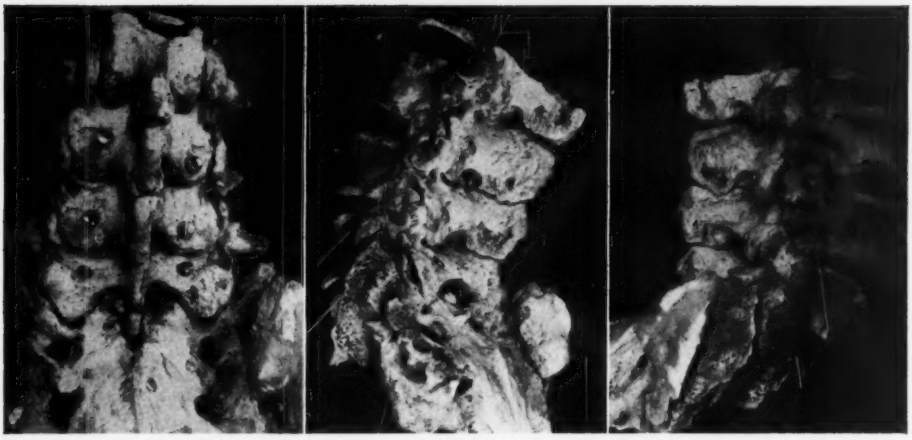

FIG. 12

Photographs of a cadaveric specimen with screw fixation. One screw can be seen emerging from the body of L.4 at the base of the pedicle, in the right-hand picture.

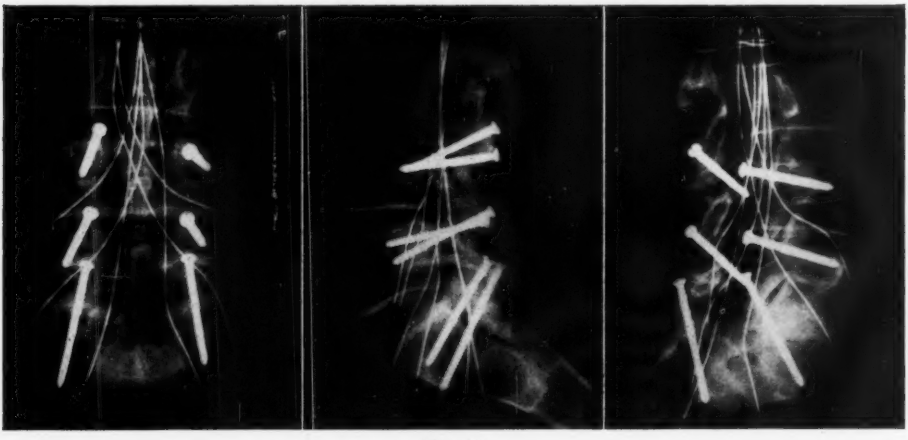

FIG. 13

Radiograph of cadaver specimen with screw fixation showing the relationship of the screws to the nerve roots. (Stainless steel wires have been passed along the nerve roots to show their position.)

developed after the operation by the author and the loose screw had to be removed. At that time the fusion area was seen to be solid, but when he returned to his own country some months later the wound was still draining.

Breaking of screws—Post-operative radiographs showed that one screw had broken in each of two lumbo-sacral fusions which in themselves were sound. As both patients were radiographed immediately after operation and about twelve weeks later, it was supposed that the screws had broken as a result of strain soon after the operation. One screw was seen to be broken in the radiographs taken immediately after operation (Fig. 9), but was not removed, and a sound fusion followed without delay. Bending of screws is not uncommon.

Nerve root irritation—This occurred on two occasions. One patient undergoing lumbo-sacral fusion for degenerative changes without signs in the leg developed severe sciatic pain and

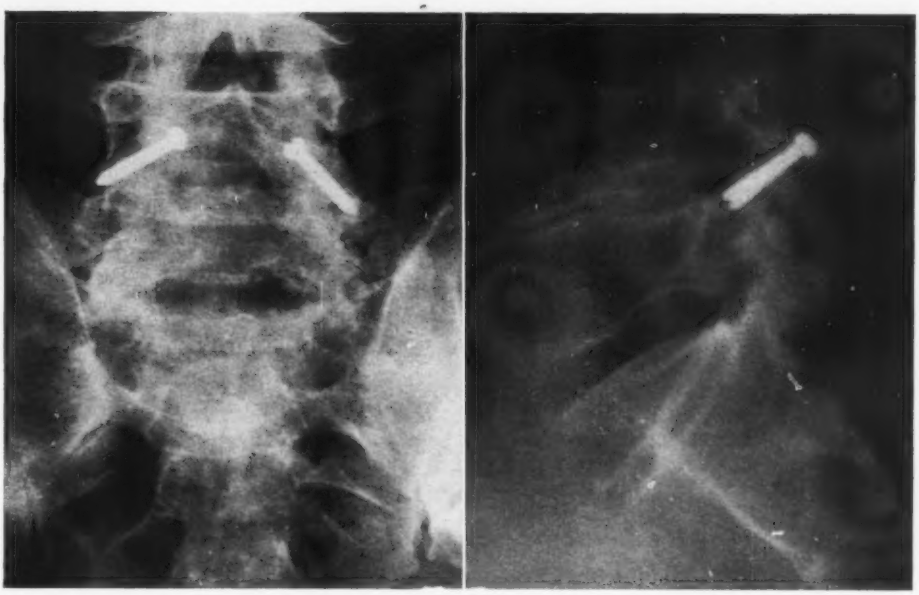

FIG. 14
A fusion at the lumbar 4–5 level in 1951.

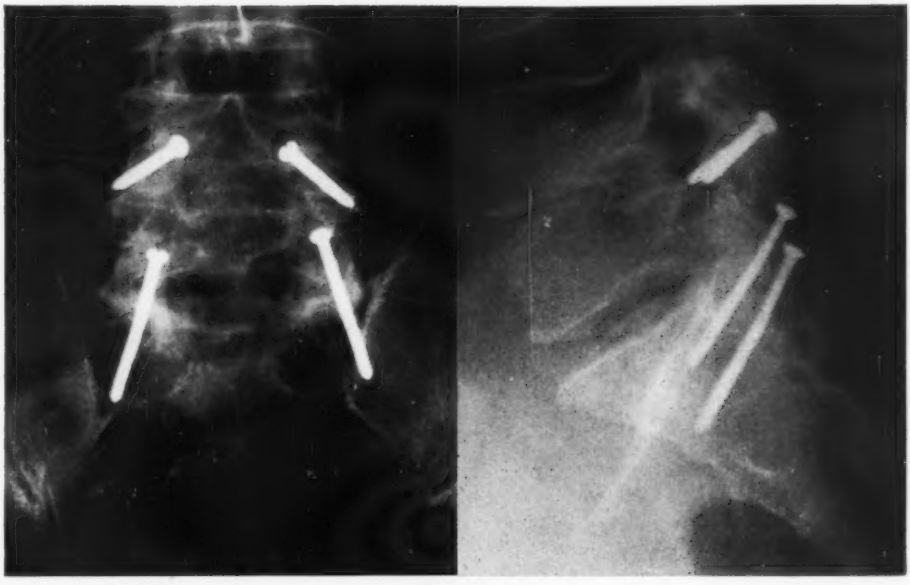

FIG. 15
Degenerative changes of the lumbo-sacral disc caused recurrence of backache in the patient shown above. Lumbo-sacral fusion in 1956, accompanied by laminectomy, gave complete relief.

spasm in both legs immediately after operation. The screws had been directed in an antero-posterior direction rather than obliquely (Fig. 10) and were identically placed. It was surmised that there was contact with the second sacral nerve root on each side. The signs and symptoms persisted for months, the pain gradually became less, but spasm remained with considerable hypoaesthesia. When the patient was last seen some three years after operation, forward bending and straight leg raising were still markedly restricted without pain, but considerable numbness was present. There has been no backache since the operation. Although the patient had been advised that removal of the screws would probably relieve the signs and symptoms of root irritation, further operation has been refused. Severe unilateral sciatica was present in one patient immediately after a spinal fusion between the fourth and fifth lumbar vertebrae. Radiographs (Fig. 11) showed that a poorly placed screw on one side had projected beyond the vertebral body to touch the nerve root as it emerged from the intervertebral foramen. The screw was partially withdrawn and the sciatica disappeared. This complication was due to an error in technique in both operations, and since it occurred only twice in this series it seems that there is sufficient margin for error to allow elimination of this complication by using greater care (Figs. 12 and 13).

Development of degenerative changes in the disc adjacent to the fusion area after operation—This is known to have happened in two patients. A lumbo-sacral fusion for disc degeneration was done in a healthy young matron and was followed several years later by degenerative changes in the disc above. Review of the original radiographs showed early degenerative changes which had been overlooked. A heavily built man aged forty years developed degenerative changes in the lumbo-sacral region five years after fusion between the fourth and fifth lumbar vertebrae (Fig. 14). Successful fusion of these areas was followed by the disappearance of complaints in both of these patients (Fig. 15). It is to be expected that, in a longer follow-up of this series, other patients may develop degenerative changes at neighbouring levels, but the early incidence seems low. This development has been estimated by Friberg (1954) to be 8 per cent in his series.

Thrombophlebitis and embolism—There was no known instance of this complication in any of these patients.

CONCLUSIONS

In spinal surgery neither clinical nor radiographic examination can at times decide with certainty the question of success or failure in obtaining a sound fusion. Certain operations may not produce consistently good results when done by different surgeons, and no one operation may always be successful. An unusual physiological condition may exist in an apparently healthy patient which renders him unfit for bone surgery. Not uncommonly, non-union of simple single and multiple fractures occurs when reduction has been considered satisfactory and has been well maintained. Nevertheless, it seems that adequate splinting, such as is obtained by the use of long, well placed screws, the careful preparation of the fusion area and the addition of well packed cancellous bone will allow early activity and reduce the incidence of failure of spinal fusion.

SUMMARY

1. A relatively simple method of spinal fusion with internal splinting by screw fixation has been described. Complications have been few.

2. Emphasis is placed upon thorough removal of soft tissue, correct placement of screws of good length, the exposure of bleeding bone wherever possible in the fusion area, and the use of well packed cancellous bone.

3. There is enough spongy bone in one posterior superior iliac spine for an ordinary spinal fusion, and, if more is needed, the other is readily available through the same skin incision. Not only is cancellous bone more desirable than a massive cortical graft, but the leg is spared, allowing early walking and freedom from complications in the limb.

4. The lateral articulations are left intact.
5. Screw fixation has eliminated the use of external support except in spondylolisthesis, or when so much bone has been removed during laminectomy that good fixation cannot be obtained.
6. Early, sometimes immediate, relief of symptoms is usual after operation, and early walking with moderate activity is desirable.
7. When the operation was done for degenerative changes with no apparent defect in the laminae there was no radiological evidence of failure of fusion after operations at one level, but two failures were found after attempted fusions at multiple levels.
8. Root irritation from screw contact in two patients was due to faulty technique. A method of screw placement to avoid this complication is described and illustrated by radiographs and photographs of a cadaver specimen.
9. There has been no known instance of an adverse psychological effect from the use of screws. Rather, there has commonly been a lively and healthy interest shown in the factor which has allowed early activity.

I wish to express appreciation for the drawings by Nan Cheney, medical artist, University of British Columbia, and for the preparation of the anatomical specimen by Mr F. J. Nichols, Laboratory Technologist, Department of Pathology, Shaughnessy Hospital, Vancouver, B.C.

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POSTERIOR FUSION OF THE SPINE FOR SCOLIOSIS

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This clinical and radiographic study of a series of patients treated for idiopathic, paralytic and congenital scoliosis was made to determine how far posterior spinal fusion could be relied upon to prevent increasing deformity, and how far it could be depended upon to maintain correction of deformity secured by various types of plaster jacket with or without preliminary operation.

In the Robert Jones and Agnes Hunt Orthopaedic Hospital there has been an experience of correction of scoliosis by plaster jackets of the Abbott type over a period of more than thirty years, the late McCrae Aitken making this the greatest of his life endeavours. He tried to derotate the more mobile vertebrae, fixing prominent parts of the chest wall by the plaster jacket and encouraging respiratory excursion of the flattened ribs through windows cut in

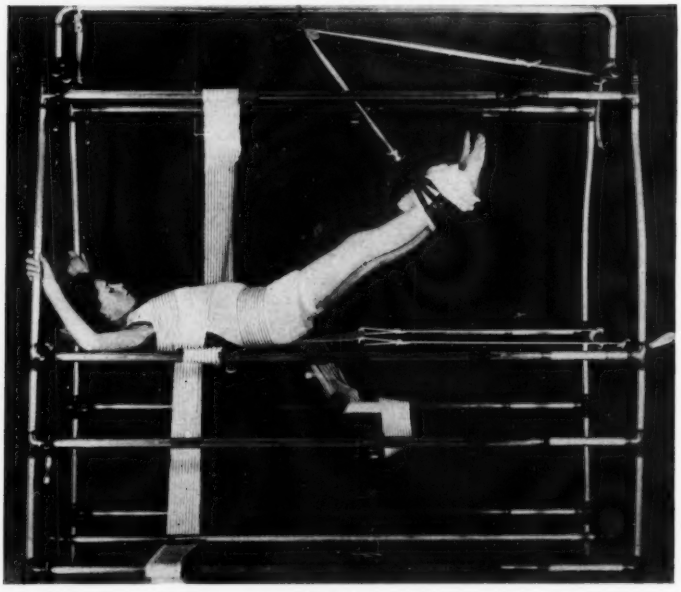

FIG. 1

Patient on the Abbott frame prepared for application of Abbott plaster jacket.

the plaster. Hour after hour the staff of the hospital applied and reapplied the jackets, instructed the patients day by day in their deep breathing, and encouraged and cajoled them to use that part of the chest wall that would derotate the curve. Figures 1 to 3 show the type of Abbott jacket applied, though it must be noted that McCrae Aitken would have insisted upon larger windows over the left chest anteriorly and the right chest posteriorly than were used in this particular patient. In many patients excellent correction was achieved and sometimes it was maintained (Figs. 4 and 5). Unfortunately the regime of plaster jackets

with respiratory exercise needed to be continued for several years. Moreover, even when good correction had been secured there was often relapse.

Quicker methods of correcting the deformity were developed by Risser (1948) with his turnbuckle jacket (Fig. 6). A still simpler and even more rapid method of correction was developed in this hospital by Sister H. Arthur and the plaster-room staff under the direction of Mr H. Osmond-Clarke and others by a simple wedging jacket which incorporated either one upper limb or one lower limb, according to the level of the curve, the plaster being wedged at twice-weekly or thrice-weekly intervals (Fig. 7). In this way the angulatory element was attacked primarily, with secondary correction of the rotation, in contradistinction to the Abbott principle of attacking the rotational element first.

FIG. 2

FIG. 3

Corrective Abbott jacket applied. Note the holes cut over the front of the chest on the left side and the back of the chest on the right side to help respiratory exercise in derotating the scoliotic spine (in this particular case the holes should have been still larger).

No matter what technique was used to secure such correction as was possible of the scoliotic curve, the problem of relapse remained. Attempts have been made throughout the world to achieve stability of the corrected deformity by posterior spinal fusion (Hibbs, Risser and Ferguson 1931; Cobb 1948 and 1952; von Lackum 1948). Most of these operations have been done after preliminary correction of the deformity by plasters of the Abbott, Risser or wedge type. In some there has been a preliminary excision of the posterior spinal elements of four or five adjacent segments of the vertebral column by which to gain still greater initial correction, as suggested by Somerville (1952); or resection of multiple wedges composed of vertebral bodies and disc at the apex of the curve, as practised in this hospital by Roaf (1955). In other patients the posterior spinal fusion was intended primarily to stabilise the existing position of the deformed spine without special regard to preventing increasing deformity, as for example in severe poliomyelitis where bone fusion of the spine could help to prevent collapse of the trunk from extensive paralysis; or in older patients where aching pain in the

back and radicular pain, together with pain from impingement of the collapsed thoracic frame against the pelvic brim, might be relieved.

CLINICAL MATERIAL

It is perhaps open to criticism that so many types of scoliosis are being grouped for one clinical study. It may be said that there are so many variables in the etiology and curve patterns, the skeletal and chronological ages of the patients, the stature and weight, the endocrine balance and the varying techniques of plaster correction with or without operative resection of bone before posterior spinal fusion, that the study is invalidated. Nevertheless

FIG. 4

FIG. 5

Figure 4—Marked thoraco-lumbar idiopathic curve in a boy of nine. Figure 5—Radiograph three years after continuous wearing of Abbott jackets with respiratory exercises to derotate the spine.

it must surely be true that the forces producing, perpetuating and aggravating curvatures of the spine have a basic similarity whether in idiopathic, poliomyelitic or congenital curves. It must be useful to know how far these tendencies to increasing deformity of the spine can be controlled by operative spinal fusion by posterior grafting. Therefore, a series of nearly one thousand patients with scoliosis treated at this hospital, of whom sixty-six had surgical fusion of the thoraco-lumbar spine as part of their treatment, has been reviewed. The proportion of patients with scoliosis who had fusion operations represents 7 per cent of the total. This compares with 6 per cent in Cobb's (1948) series.

It will be understood, therefore, that only the more difficult and the more severe scoliotic deformities were subjected to operative treatment. In studying the tables of analysis it should

be remembered that no single patient with a primary curve measuring less than 22 degrees was so treated. There were no lumbar pattern curves in the idiopathic group that needed fusion; they were treated in other ways without difficulty. Though radiographic and strictly mathematical measurement might have suggested a deformity of severe degree they were not deformities of clinical significance.

Of the sixty-six patients now reviewed only those with a follow-up period of from three to ten years are included; eleven patients with a review of only two years are excluded. This leaves fifty-five patients: idiopathic scoliosis thirty-three; paralytic scoliosis eleven; congenital scoliosis eleven (Table I).

Age—The age of the patients at the time of fusion is shown in Table II. Only one patient was under ten; most patients were between eleven and twenty, with an average age of fifteen. Only five patients were over twenty at the time of operation, and in them the operation was undertaken for pain or instability.

FIG. 6

The Risser jacket (arm excluded in this case) showing turnbuckle opened to its extreme.

METHOD OF TREATMENT

In every case, after initial correction or reduction of the deformity, the spine was exposed through a midline incision, the laminae and spinous processes were freshened subperiosteally and fragmented, the facet joints were denuded of cartilage so far as this was possible, and the area was packed with thin slivers of bone shaved from the tibia, together usually with strips of cancellous bone cut from the crest of the ilium on one or both sides, and sometimes supplemented by frozen bone from the bone bank. As a rule the operation was done through a large "window" while the corrective plaster was still in position.

TABLE I

CLINICAL MATERIAL (FIFTY-FIVE CASES)

Idiopathic scoliosis . .	33
Paralytic scoliosis . .	11
Congenital scoliosis . .	11

TABLE II

AGE AT WHICH FUSION WAS UNDERTAKEN

	5–10 years	11–20 years*	21–35 years†
Idiopathic scoliosis	—	30	3
Paralytic scoliosis	—	9	2
Congenital scoliosis	1	10	—

* Average age of this group fifteen years.

† In these patients the operation was not done to prevent increasing deformity but to stabilise a collapsing spine, or to relieve pain.

Usually a new plaster was applied three weeks after operation. An important point in treatment arises here. No matter what correction by wedged or turnbuckled jackets may have been gained before operation, a still greater degree of correction was often possible at the time

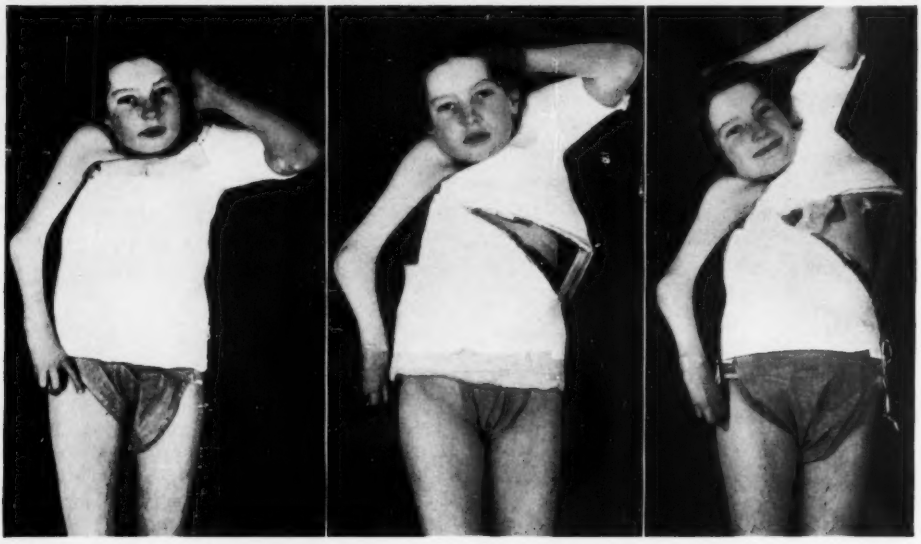

FIG. 7

This simple wedging jacket is easy to apply, includes an arm or leg (or both), and correction is achieved in stages by spreading the jacket open over a block placed at the fulcrum.

of application of a new plaster three weeks after operation. Sometimes when this plaster was applied on the Abbott frame a surprising degree of additional correction was obtained. Thereafter the spine was immobilised in plaster in recumbency for about six months (sometimes rather less) and continued in an ambulatory plaster jacket for at least a further six months (sometimes rather longer). The plaster jacket was not discontinued until it was thought that there was radiographic evidence of sound union of the surgically fused area of the spine. It must be noted, however, even before examining the results of the study, that radiographic interpretation of " sound fusion " of the bone-grafted spine can always be fallacious.

RESULTS

Table III shows the incidence of relapse after spinal fusion in the three types of scoliosis—the term " relapse " implying a failure to maintain the full correction obtained before operation, not a return to the original deformity.

TABLE III

RELAPSE* AFTER SURGICAL FUSION AS MEASURED RADIOGRAPHICALLY

	Spines fused	Relapsed
Idiopathic scoliosis	33	29
Paralytic scoliosis	11	9
Congenital scoliosis	11	6

* In this table the term " relapsed " means that the full correction was not maintained. It does not mean that the deformity recurred to its original degree. Many classified as " relapse " were clinically much improved.

The important feature was that in forty-four cases out of the fifty-five (80 per cent) relapse occurred to a greater or lesser degree. This figure is higher than was expected from clinical reviews.

The fact that the highest incidence of relapse occurred in patients with idiopathic scoliosis is also surprising; it was expected that those with paralytic curves would show the highest rate because of their instability and the effects of superincumbent body weight. Another unexpected finding was that the congenital curves were held most successfully, despite the fact that nine of the eleven curves were progressing when treatment was begun.

Table IV shows that, when some correction was gained before operation, relapse occurred after fusion in forty-one out of forty-five cases. This is a disturbing number, and it is to be noted that all the idiopathic curves relapsed, regardless of their pattern. All except two of the paralytic curves relapsed, and those two were in patients over twenty-one in whom fusion

TABLE IV

RELAPSE AFTER SURGICAL FUSION IN RELATION TO PRELIMINARY CORRECTION OF DEFORMITY

Type of scoliosis	Curvature corrected before fusion	Relapse after fusion	Curvature not corrected before fusion	Relapse after fusion
Idiopathic .	28	28	5	1
Paralytic .	11	9	—	—
Congenital .	6	4	5	2

was done to stabilise the spine rather than to prevent progression. Two congenital curves remained corrected, but one had full compensation, was not progressing, and was corrected only very slightly: the other, in a boy aged eight, was corrected by 14 per cent and the correction was fully maintained for over ten years.

Of the cases in which no correction was gained before operation (ten in number) three curves became worse: these were progressive when treatment was started. Of the seven that did not become worse four were progressing at the time of treatment but growth of the spine was nearly complete; and the other three were not progressing and growth of the spine was complete.

Fusion therefore failed to maintain the corrected spine but succeeded in holding the uncorrected curve.

TABLE V

RELAPSE AFTER SURGICAL FUSION IN RELATION TO THE DEGREE OF CORRECTION OF ORIGINAL DEFORMITY

Type of scoliosis	Correction of less than 20 degrees gained before fusion	Relapse after fusion	Correction of more than 20 degrees gained before fusion	Relapse after fusion
Idiopathic .	16	16	12	12
Paralytic . .	9	7	2	—
Congenital .	2	2	4	2

It is worth mentioning at this point that it is difficult in any type of scoliosis to obtain a true correction of more than 40 degrees by conservative means: in this series only six patients out of the fifty-five gained that amount of correction. Correction of over 20 degrees was common both in thoraco-lumbar idiopathic curves and paralytic curves, but was uncommon in thoracic idiopathic curves and congenital curves—the latter two resembling each other in many respects. Nearly all the thoracic curves that relapsed were in the group corrected by less than 20 degrees: this indicates how resistant they are to correction and how prone they are to relapse.

In Table V the curves are divided into two groups—those corrected by more than 20 degrees and those corrected by less than 20 degrees. The figures show that relapse bore no relation to the amount of correction achieved.

It may thus be safely stated that relapse is to be expected when any correction has been gained.

ASSESSMENT OF AMOUNT OF RELAPSE

It has been found preferable, in assessing the amount both of correction and of relapse in a curve, to record figures as a percentage rather than in degrees. For example, a curve of 100 degrees that is corrected to 60 degrees has been corrected by 40 per cent. If that 60-degree curve subsequently relapses to 80 degrees after fusion, a 50 per cent relapse has occurred. This method of recording gives a much clearer picture of the success or failure of the treatment.

Table VI shows that an average correction of 38 per cent in all curves treated was achieved by plaster-jacket correction. The least correction was in the thoracic idiopathic and congenital curves, which showed 26 per cent and 23 per cent correction respectively. The greatest correction (averaging 52 per cent) was achieved, not unexpectedly, in the thoraco-lumbar idiopathic curve patterns.

The important finding is that in all groups the average correction finally maintained after fusion was only 14 per cent. The least correction maintained was in the thoracic idiopathic curve pattern (4 per cent) and the greatest (28 per cent) was in the thoraco-lumbar idiopathic curve pattern, although it could have been as easily seen in the paralytic group.

TABLE VI

AVERAGE CORRECTION GAINED BY PLASTER JACKET AND AVERAGE CORRECTION MAINTAINED BY SURGICAL FUSION

	Average correction gained by plaster jacket	Average correction maintained after spinal fusion
Idiopathic scoliosis	(*per cent*)	(*per cent*)
Thoracic . .	26	4
Thoraco-lumbar	52	28
Combined. .	49	8
Paralytic scoliosis .	38	15
Congenital scoliosis	23	12

The other observations summarised in Table VI were the same as would be expected, except that in combined idiopathic curves an average of only 8 per cent correction was maintained when an average of 49 per cent initial correction had been gained: the radiographs of these curves, however, showed that four out of the five had been classified and treated incorrectly as thoraco-lumbar curves rather than as combined curves and, in consequence, fusions inadequate in extent were performed.

Finally, the results confirm that thoracic curves (involving the thorax only) relapsed most of all and that those curves which included more mobile parts of the spine (especially the thoraco-lumbar junction) showed better maintenance of correction.

In brief, as judged from radiographic measurements the amount of correction maintained after fusion was disappointing in the great majority of patients.

CAUSES OF RELAPSE

On the basis of these results, some possible causes for relapse after posterior fusion are offered. Some accepted theories are criticised.

Faulty radiographic measurements—Few authors have mentioned one common finding when considering their " relapsed " cases: it is that an erroneous estimate of correction was made

in the first instance. Often one finds that measurements of curves may be so inaccurate that correction (and therefore subsequent relapse) is more apparent than real. This is illustrated in Figure 8, which shows the standard method by which a curve is measured, using the Lipmann-Cobb construction. The lines drawn between the two end-vertebrae of a curve (these being the vertebrae which are most nearly neutral in tilt and rotation) may be difficult to place in the first instance, and a slight inaccuracy in angle construction may produce quite marked errors when the perpendiculars are drawn to form the angle of tilt. Further, these end-vertebrae are those that have the greatest degree of mobility, and so are easily altered in position to become part of the secondary or compensating curves. Thus even a slight change in the position of such transitional vertebrae will produce marked differences in the angle of measurement of the curve, when clearly the major part of the curve (and certainly the positions of the four central vertebrae) has been unaltered. The end-vertebrae take the greatest strain of superincumbent body weight when the upright position is regained, and all the forces

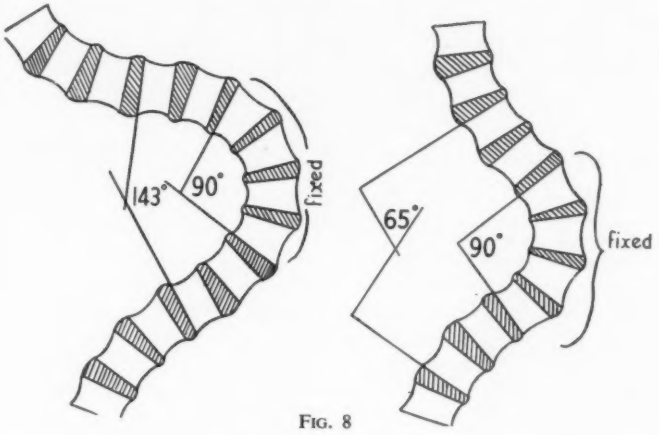

FIG. 8

Figure 8—The Lipmann-Cobb method of measuring a curve. It is clear that the 90-degree angle of the four central vertebrae has been unchanged whereas the remainder of the primary curve has been reduced from 143 degrees to 65 degrees.

FIG. 9

Figure 9—The black line shows the curve before correction, the dotted line after correction. The common central part of the curve remains unchanged in position and degree.

responsible for aggravating a scoliosis encourage these vertebrae to revert to their former position in the primary curve; this happens quickly when they are still insecurely tethered by the recently grafted bone. Measurement of the same curve at this stage will show apparently a " relapse " when no alteration in the position of the central vertebrae in the primary curve has occurred. Figure 9 simplifies this observation.

A false estimate of correction (and so of relapse) can thus easily be made when the Lipmann-Cobb method is used. This happened with several fixed curves in this series and so presumably occurred to a lesser degree with partly fixed curves. What really happened during these various corrections was that the primary curve was altered slightly at each end and the secondary curves were increased or lengthened to produce " compensation." This term—used now in preference to correction—is difficult to define, but compensation exists when primary and secondary curves come to lie symmetrically on either side of an axis which ideally (but not necessarily) runs between occiput and midline of sacrum. It may involve bringing into the picture a tilt of the head and neck or of the pelvis, but it is usually achieved

within the limits of the spine if there are enough mobile vertebrae above and below the fixed part of the primary curve to form two secondary curves whose measurements together equal the measurement of a primary curve. If head, neck and shoulders, or pelvis and hip joints, take part in the compensatory mechanism it is an indication that true natural spinal compensation has failed.

Insufficient correction—True relapse after fusion occurs more readily when the fullest possible correction of the primary curve has not been attempted, on the supposition that compensatory curves could not be fully developed on account of structural changes in them. It is doubtful whether over-correction of a primary curve in such an instance could ever be a danger. Since relapse in the primary curve is almost invariable after posterior fusion, the aim should be to obtain as much correction as possible, disregarding the measurements of compensatory curves. Under-correction is a greater fault than over-correction which—should it ever happen—would always be adjusted later by the normal balancing forces of the body.

FIG. 10

FIG. 11

Figure 10 shows a severe thoraco-lumbar curve in a boy of seventeen. Four years after correction and fusion (Fig. 11) the spine still showed satisfactory correction clinically, but radiographic measurements showed 50 per cent loss of original correction.

Inadequate fusion—True relapse may occur when too short an area of the spine has been fused. There is no reliable guide to the extent of spine that should be fused; it depends largely upon the way in which a curve reacts to compensation, on the age of the patient, on the etiology of the scoliosis and its pattern. In children scoliosis may recur after an apparently sound fusion, just as deformity at the hip may recur after arthrodesis of the hip. It is therefore clear that grafting of the growing spine must include not only all the vertebral segments where an established abnormal growth pattern exists, but also an area of apparently unaffected spine which, in the absence of treatment, might have been taken into the primary curve. In adolescent and adult patients the fusion should usually extend from a neutral vertebra at the upper end of the main curve to a vertebra parallel to it at the lower end; and if it be accepted that over-correction is no danger the junctions of primary and secondary curves should be fused most securely. The risk of holding a primary curve over-corrected by immature grafts is negligible, but the chances of an insufficient fusion of a primary curve are great.

Pseudarthroses—Another cause of true relapse is a pseudarthrosis in the grafted area. In this series only two examples of pseudarthrosis were found and, in both, continued immobilisation led eventually to sound fusion.

Some surgeons inspect the grafted area of the spine some months after fusion to close, by further grafting, any pseudarthrosis that may be found. If the inspection fails to reveal a pseudarthrosis it does not necessarily mean that the fusion is sound: unless the broad sheet of bone that is usually seen is firmly united with the underlying laminae of all the vertebrae in the fused area (this point cannot easily be determined) pseudarthrosis exists and deformity can progress. We have had an opportunity of examining at operation several spines that appeared soundly fused, but in which there was some recurrence of deformity after correction and fusion over an adequate extent. Nevertheless I do not regard pseudarthrosis as an important or even a common cause of relapse.

SUMMARY AND CONCLUSIONS

1. Posterior fusion of the spine in scoliosis cannot be relied upon to maintain correction of the curve or to prevent progression of a vicious resistant curve. It can, however, hold to some extent the correction of a mobile curve and the compensation of a fixed curve.

2. Despite generally poor results as assessed radiographically, the clinical improvement is often gratifying. Most patients claim to be greatly improved: the spine feels stronger, there is less fatigue, and balance is better controlled. Moreover, visible deformity may be improved markedly even though the anatomical correction as observed radiographically is slight (Figs. 10 and 11).

3. It is believed that the true cause of relapse is that the bone formed from sliver grafts remains immature for a long time. Even when incorporated with the immature bone of the child's spine or the mature bone of the adult spine, it remains soft and resilient. When subjected to the stresses and strains of weight bearing and gravity, and then to the unnatural forces which initiated or perpetuated the scoliosis, this immature bone undergoes remodelling to Wolff's Law—like the neck of the femur after slipping of the upper femoral epiphysis. The forces that alter the grafted bone are not only lateral forces but also—perhaps more important—rotational forces. There seems to be a definite link between the degree of rotation and the amount of relapse, correction being maintained best when rotation is least.

I am indebted for much help to Mr H. Osmond-Clarke at whose suggestion this investigation was undertaken. Many of the patients examined were under his care at Oswestry. I am also grateful to Mr Robert Roaf for his help and advice in the preparation of this paper and for the loan of illustrations.

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LUMBAR SPINAL OSTEOTOMY

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From the London Hospital

The correction of severe rigid spinal kyphosis was first done by Smith-Petersen in 1945 as a one-stage operation, and shortly afterwards in 1946 by La Chapelle who used two stages. Smith-Petersen performed his bone division posteriorly by oblique osteotomies (Fig. 1) and snapped the anterior longitudinal ligament by manipulation. La Chapelle carried out a more horizontal bone resection and divided the anterior ligament under direct vision by an additional surgical approach anteriorly.

This paper is based on an experience of operations on just over a hundred patients, of whom eighty were available for review. The hazards of operation are considered in relation particularly to the deaths and complications. Only six of the patients were women, and all the patients were in early adult or middle age. With two exceptions, the patients have all suffered from ankylosing spondylitis or rheumatoid spondylitis, and presented with a severe rigid kyphosis, mainly cervico-thoracic as a rule. Usually the normal lumbar lordosis has been lost, this region of the spine becoming flattened or involved in the general kyphotic curve.

The object of spinal osteotomy in nearly all these patients has been to provide a compensatory lumbar lordosis for the rigid thoracic or cervico-thoracic kyphosis, and the indications for the operation are therefore as follows: 1) To enable the patient to become erect,

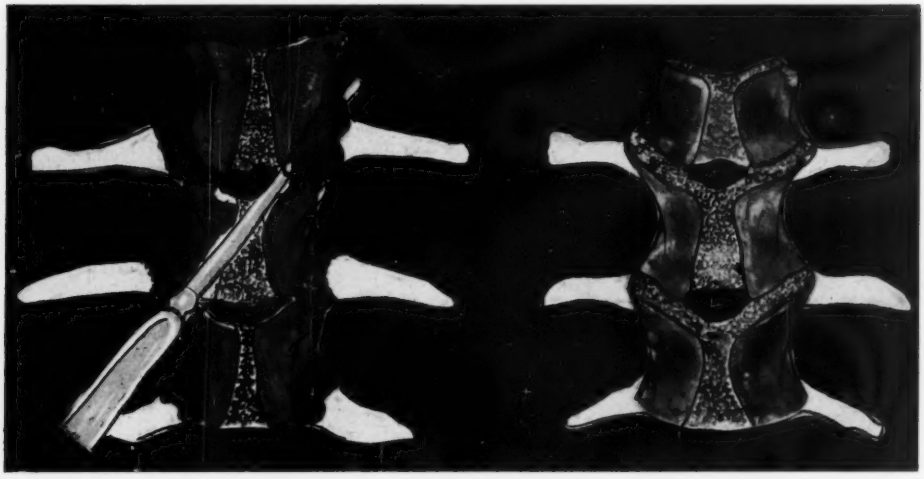

FIG. 1

A diagram (after Smith-Petersen) of the method of section of the spine in lumbar osteotomy.

thereby counteracting the effects of gravity in persistently increasing the deformity; this correction enables him to see ahead for a much greater distance, and greatly improves his appearance (Figs. 2 to 11). 2) To improve respiration by lifting the thoracic cage upwards off the diaphragm, upon which breathing depends almost entirely in most of these patients.

FIG. 2

FIG. 3

FIG. 4

Case 1—Photographs showing the appearance of a patient with ankylosing spondylitis before operation.

FIG. 5

FIG. 6

Case 1. Figure 5—Before lumbar osteotomy. Figure 6—Radiograph after operation.

3) Similarly, by relieving pressure of the costal margin on the upper abdominal viscera, to improve gastrointestinal function; many patients have noticed both improved appetite and digestion. 4) Occasionally to enable the abdominal surgeon to have an adequate approach when major gastric or intestinal surgery is required.

FIG. 7

FIG. 8

FIG. 9

Case 1—Appearance of patient after lumbar osteotomy.

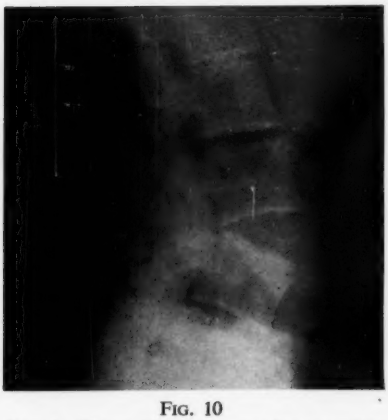

FIG. 10

FIG. 11

Case 1. Figure 10—One year after operation. Figure 11—Five years after operation. There has been very little loss of correction.

DETAILS OF THE OPERATION

The Smith-Petersen method has been followed entirely, the correction being attained in a single operation. Difficulty in rupturing the longitudinal ligament was encountered only very occasionally. Slight differences in the detail have been developed as the series progressed, and on the whole a much greater correction has been planned and achieved than was ever conceived originally in osteotomy at a single level.

Combined local and general anaesthesia has been used, the former with adrenaline and the latter with intratracheal intubation, which requires great care because of the danger of cervical fracture-dislocation. More recently, fluothane low pressure anaesthesia has provided an excellent operation field without any undue disturbance to the patient.

The prone position with suitable supporting pillows or sponge rubber cushions has been used throughout the series in preference to the lateral one. The diaphragm must be allowed to move freely and care taken with the position of the head, in addition to any necessary upward tilting of the whole patient when fluothane is being used.

The operation has been performed where ossification or calcification in the anterior longitudinal ligament is least; otherwise as high up the lumbar spine as possible. On the whole, lumbar 2–3 has been the level of choice, lumbar 1–2 being followed by a greater tendency to ileus, possibly from irritation of the splanchnic plexus. No apparatus has been used to obtain correction, because manual control with the body weight of the patient has proved easy, safe and quick, and avoids the danger of an excessive leverage, particularly in patients who are ankylosed from head to foot.

Through the usual mid-line lumbar approach the muscles are stripped laterally by subperiosteal dissection as far as the articular processes and the remains of the intervertebral joints. Part of the spinous process at the lower limit of the intended osteotomy is removed, the amount being judged to allow the required correction in a stable manner, enabling the superior spinous process to hinge down on to the remainder of the inferior one. The ligamenta flava and interspinous ligament are removed: these are usually ossified; so their removal has to be done with fine gouges and bone-nibbling forceps. The theca and cord are thus exposed centrally. It is difficult to avoid penetrating the subarachnoid space, because the theca is often very adherent.

Osteotomies are then made on both sides across the line of the articular processes at an angle of about 45 degrees to the frontal plane from a point just clear of the margin of the theca. The completed osteotomy enters the intervertebral foramen above, and care has to be taken not to damage the nerve root. The actual osteotomy line is made about 1–2 millimetres wide, and the instruments most suitable for performing this important part of the operation are fine straight osteotomes and narrow pointed bone-nibbling forceps. The depth of the bone both here and in the ossified ligamenta flava is surprisingly great—often as much as one or two centimetres.

When the osteotomies are completed a certain amount of instability is evident, and the correction is then achieved by hinging the part of the spine above on that below, in the course of which the anterior longitudinal ligament is both felt and heard to rupture with a distinct thud, or a loud snap when it is entirely calcified or ossified. The wedge-shaped gap closes down and this readily controls any bleeding that there may be from the raw bone surfaces or perivertebral veins. The obliquity of the osteotomy lines gives lateral stability, and the coaptation of the spinous processes prevents excessive angulation. A wire loop or suture is inserted between the spinous processes, more as a marker than to give any real internal fixation, and the surrounding bone surfaces are prepared for grafting by elevating osseous flaps and inserting the bone chips obtained in the earlier part of the operation.

As a rule fusion occurs readily and consolidation in as short a time as three months, though protection is essential for longer. The osteotomy lines must be cut cleanly, so that they glide smoothly on one another. When they are uneven the vertebra above may be displaced backwards on the vertebra below (Figs. 17 to 19). If the theca is inadvertently opened it is wise to suture the hole to prevent excessive loss of cerebrospinal fluid, and before closure of the wound haemostasis must be perfect.

The patient is immobilised in the corrected position in a plaster jacket, which includes one thigh to give more complete fixation and to make nursing easier. After six weeks the plaster is changed, the sutures are removed and an ambulatory plaster jacket is applied. For

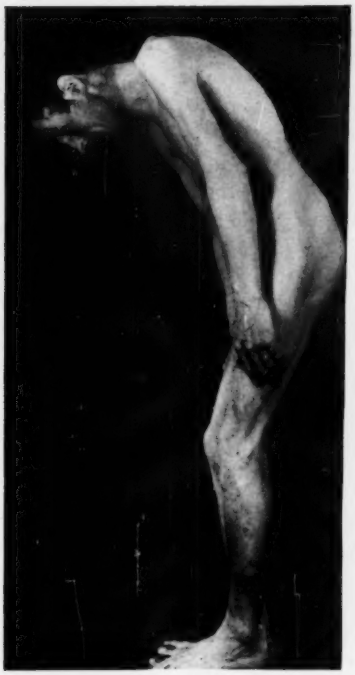

FIG. 12

FIG. 13

Case 2—A patient with a severe thoracic kyphosis seen before and after operation.

FIG. 14

FIG. 15

FIG. 16

Case 2—The radiographs of the patient before operation are shown in Figure 14, immediately afterwards in Figure 15 and three weeks later in Figure 16 when additional extension had occurred.

FIG. 17 FIG. 18 FIG. 19

Case 3. Figure 17—Radiograph of a patient with ankylosing spondylitis before operation. Figure 18 shows that there has been inadvertent backward displacement at the osteotomy. Fortunately there was no cord displacement and after six months the spine has " settled down " at the osteotomy site (Fig. 19).

both these plasters the two-table technique is used to maintain the hyperextension, the head end of the patient being guarded very carefully, particularly if the cervical spine is ankylosed. If, in addition, the hips are ankylosed, even greater care has to be taken, as leverage can then be extreme. Usually, it has been found preferable to carry out hip arthroplasty for bilateral ankylosis with flexion deformity before spinal osteotomy, in spite of the necessity for a period of further immobilisation, and even plaster fixation of one leg for a period of six weeks. The correction of the hip flexion deformity enables a more accurate estimation of the intended spinal correction, and makes the spinal osteotomy safer, the patient being no longer a rigid pillar of bone. Recently internal fixation with metal plates has been employed in an effort to dispense with plaster immobilisation (Fig. 20). Experience has shown that after the first few days a posterior plaster shell makes nursing easier and the patient more comfortable.

FIG. 20
Internal fixation at the time of osteotomy of the lumbar spine.

In the lumbar region the degree of correction achieved at a single osteotomy site has usually been between 25 and 45 degrees, but in one case a correction of nearly 90 degrees was obtained at the lumbar 4–5 level without any nerve damage except a slight temporary peroneal weakness (Figs. 12 to 16). This marked correction was accidental and the result of not having the base of the spinous process above firmly embedded on the remaining portion of the spinous process below, too much of which had been resected. In the great majority of cases a good compensatory

lumbar lordosis from adequate lumbar correction has made cervical thoracic osteotomy unnecessary. Costo-vertebral ankylosis makes thoracic osteotomy extremely difficult.

During the last year cervical osteotomy has been performed successfully in cases of marked cervical kyphosis, but it will be described in a separate paper.

RESULTS AND COMPLICATIONS

Deaths—Eight patients died from complications of the operation. The causes were: accidental suffocation 1, perforated ulcer and peritonitis 1, acute gastric erosion 1, thrombosis of spinal cord—acute psychosis 1, cervical fracture and cord injury 1, amyloid disease and renal failure 1, anoxic encephalopathy, shock or cause unknown 2.

The accidental suffocation resulted from turning a patient some twelve hours after operation and failing to realise the danger during sleep that the head might sink into the pillows and become buried because of cervical ankylosis. This was a nursing error and should be avoided. Possibly this patient should be included with the anoxic cases described later.

FIG. 21

Necropsy specimen of spinal osteotomy in a patient who died from gastric perforation. The adaption of the contents of the spinal canal to the correction is well shown.

The acute abdominal complications of perforation and gastric erosion caused death four days and one day after operation respectively. The osteotomy site in the former patient is shown in Figure 21. The plaster made diagnosis difficult, but clearly if a patient has abdominal pain such complications must be considered and the plaster split with removal of the anterior shell to allow complete abdominal examination. Laparotomy could be performed if necessary with the patient in the posterior plaster shell. The level of the osteotomy in both patients was lumbar 2–3, and it is possible that pull on adhesions could be related to the abdominal complications.

Cord lesions occurred in two patients and led to death from terminal bronchopneumonia. In one, thrombosis of the spinal cord vessels may have been precipitated by forward displacement of the upper vertebra at the osteotomy site, with post-operative flaccid paralysis, partly relieved by manipulative correction; pressure sores on the upper part of the back and bronchopneumonia proved fatal four months after operation. This patient also had a severe acute maniacal psychosis, which made nursing very difficult, as at one stage he removed his own plaster and later refused to stay in a plaster bed.

In the other patient with a post-operative flaccid paralysis death occurred one week after operation, and a fracture-dislocation with spinal cord pulping at the cervical 6–7 level was found at necropsy. This may have occurred at one of several stages during the operation, such as during intratracheal intubation, placing the patient on the operation table, carrying out the spinal extension at the osteotomy, applying the plaster or finally lifting the patient on to the theatre trolley or bed. No force must be exerted on a rigid cervical spine.

Amyloid disease is a recognised complication of ankylosing spondylitis and was the cause of death from renal failure in one patient four months after operation who had made a good

initial recovery, and who had shown no previous signs of renal insufficiency. Before operation these patients must be assessed for renal function as well as vital capacity.

Shock caused the death of two patients in less than twenty-four hours after operation, and at necropsy nothing abnormal could be found. The term anoxic encephalopathy has been used in such cases, implying that the head-down position may deprive the vital centres of adequate oxygen supply, and if this is the case the operation table must be tilted so as to keep the patient's head level during the operation. The possibility of fat embolism was also considered, but was not confirmed on detailed investigation. An absence of fatal chest complications is to be noted, particularly as many of these patients had a vital capacity of less than fifteen hundred cubic centimetres.

Non-fatal complications—*Spinal cord* irritation with some residual spasticity in the legs occurred in one patient from haemorrhage around the cord in the lower thoracic region well above the osteotomy site. The cord was decompressed by laminectomy with good effect, but the patient required elbow crutches for weight bearing because weakness of the lower limbs persisted.

Nerve root damage with temporary foot drop occurred in one patient, and in two others paraesthesiae were noted. The probable cause was stretching of the nerve roots just above the osteotomy site with a correction of more than 45 degrees.

High intestinal obstruction in a severe form occurred in one patient from strangulation by the superior mesenteric vessels. This was relieved completely by duodeno-jejunostomy and a good recovery was made. The level of the osteotomy was lumbar 2–3.

Ileus of a minor degree has occurred in several patients and was usually relieved quite quickly by making a window in the plaster and by the appropriate medical measures. A slight haematemesis probably from gastric erosion occurred in one patient with complete recovery.

Psychological upset in a less severe form than the acute mania already mentioned is understandable when correction from very severe deformity is achieved suddenly and somewhat dramatically. In only one patient has special medical treatment been required, but a sympathetic approach to a patient's altered outlook and to the reaction of the relations and friends can be very important.

Recurrence of deformity, severe enough to warrant further correction, has been observed in three patients. In two of these the angle at the osteotomy site decreased, probably because of incomplete bone consolidation, after the patient had got up. It is not easy to determine whether the posterior fusion is sound; so the use of a posterior spinal support for about a year after operation is recommended, together with careful and regular follow-up examination. In another case spinal deformity increased above the level of the osteotomy and called for a second operation.

The low incidence, in ten years, of loss of correction after the operation has been very satisfying. Usually a few degrees are lost in the course of consolidation, but not enough to make further operation necessary. On the other hand, the mortality rate has been high, and measures must be taken to reduce this in the future. Acute abdominal complications are much less likely to prove fatal if they are anticipated, and nursing errors can be avoided.

Many of the patients in this series had gross deformity, and the incidence of complications is bound to be reduced if the operation is employed earlier in the disease. It has to be realised that gross spinal deformity can occur in spite of conservative measures such as plaster beds and spinal braces. The patient with ankylosing spondylitis involving the whole spine requires regular observation, and the value of breathing exercises to maintain diaphragmatic excursion and vital capacity must not be overlooked. It is doubtful whether the operation increases vital capacity, because the thoracic cage is still rigid, but certainly the patients seem to benefit from easier diaphragmatic excursion, and their mental as well as physical outlook is much improved.

SUMMARY

1. The indications for correction of severe rigid kyphosis by lumbar osteotomy are described.
2. The fatal complications in a series of a hundred cases are listed. With more experience of this operation they should be considerably reduced.
3. Among the non-fatal complications the low incidence of recurrence of the deformity severe enough to require further operation is noteworthy.

A tribute must be paid to the anaesthetists, Dr G. P. Fox, Dr D. C. R. R. Jenkins and Dr G. B. Badock, who so skilfully performed intratracheal intubation in nearly every patient, and who have played a very important part in controlling the head end of the patient at the time of carrying out the spinal correction. Also the nursing and physiotherapy staffs at the London Hospital, the Robert Jones and Agnes Hunt Orthopaedic Hospital and the Orsett branch of the Tilbury Riverside Hospital have contributed much skilful work in the care of these patients after operation. My thanks are also due to many colleagues for so kindly referring their patients to me.

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PARALYTIC DISLOCATION OF THE HIP*

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The hip is one of the joints at which instability cannot be controlled adequately by splinting. It is therefore important that disability resulting from paralysis should not be further aggravated by subluxation or dislocation if this can be either avoided or corrected. In the older patient stability can, in favourable circumstances, be obtained by arthrodesis of one hip, but in young children this is not practicable, and it is in young children that this problem is particularly important, because it is only in young children that dislocation develops (Blundell Jones 1954).

This paper refers to the dislocations developing in consequence of flaccid paralysis and is not concerned with the subluxation commonly found in association with spastic paraplegia; it is concerned only with the mechanics of dislocation and with the methods that may be used to secure an immediate reduction. It is not concerned with the second factor that is of great importance in all dislocations in infants, namely the subsequent growth of the hip joint and the bones comprising it.

MECHANISM OF DISLOCATION

The dislocation has been described as developing in two ways. Blundell Jones (1954) considered coxa valga important. Watson Jones (1926) attributed the dislocation to the development of an adduction contracture. In fact the mechanism of development of dislocation by both of these methods is the same. The nearer the angle between the neck of the femur and the horizontal of the pelvis approaches 90 degrees the more unstable will the hip become. This might well be called the "effective valgus" of the femoral neck (Fig. 1) and will be equally damaging whether caused by true coxa valga, obliquity of the pelvis or adduction of the hip; but obviously the method of treatment will vary in each instance, and for the purposes of description we may consider two types—true paralytic dislocation and postural paralytic dislocation.

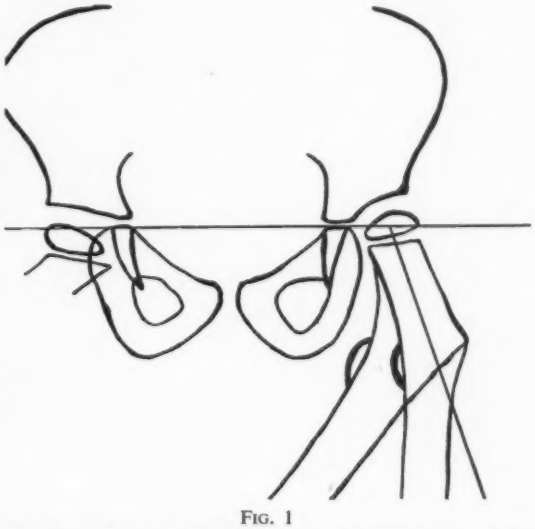

FIG. 1

Drawing to demonstrate the importance of the "effective valgus" of the femoral neck which may be produced in different ways.

TRUE PARALYTIC DISLOCATION

In this condition the immediate cause of the dislocation lies within the hip itself. The muscles are paralysed, the ligaments stretched and excessive coxa valga is present; in fact the neck and shaft may be in the same straight line. These circumstances inevitably lead to instability with progressive subluxation leading

* Presented to the Meeting of the Royal Society of Medicine in Oxford in May 1956.

to dislocation and deformity of the acetabulum. These changes are secondary, and are reversible up to a certain point, but beyond this they become established. For this reason it is important that the deformity be corrected early. If a policy of "wait and see what happens" is followed, by the time the result is seen it will be too late to do anything about it. Splinting has little practical value. The changes leading to the dislocation are not self-correcting; so, although the dislocation can be reduced and the reduction maintained by a splint, when the splint is removed the dislocation will recur. Nevertheless, if the child is unfit for operation intermittent splinting with the leg in abduction will help to reduce the damage to a minimum until such time as operation becomes possible.

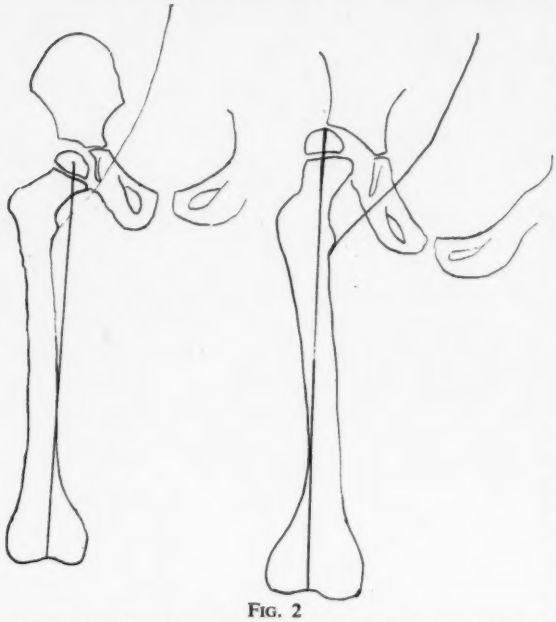

FIG. 2

Diagram showing the change of action of the psoas. In the normal hip it is a medial rotator, but in a subluxated hip or one with a valgus anteverted neck it becomes a lateral rotator.

Of the three factors mentioned as the cause of instability—paralysis, ligamentous laxity and coxa valga—we can do nothing useful about the first two, but fortunately we can easily correct the last with great benefit, as has been shown by Blundell Jones (1954) who corrected the valgus by an osteotomy at the base of the neck. Whether or not anteversion plays a part in this condition is of only minor importance, but the question of rotation is important and should be taken into consideration.

A paralysed and dislocated hip will often lie in lateral rotation. The reason for this is shown in Figure 2. The axis of rotation of the femur extends from the centre of the head of the femur to the centre of the knee joint. As is shown in the diagram, the attachment of the psoas to the lesser trochanter lies outside this axis; so the psoas muscle is a medial rotator of the normal hip. If the neck of the femur is valgus or anteverted the lesser trochanter will be approximated to this axis and may even come to lie medial to it, so that the action of the psoas will be reversed and it will become a lateral rotator of the hip. If the head of the femur is dislocated from the acetabulum it will no longer be one end of the axis, and the psoas will then be a strong lateral rotator. If this faulty mechanism is corrected by reduction of the head of the femur into the acetabulum and an adduction osteotomy to correct the neck-shaft angle, the normal action of the psoas will be restored and if it is functioning at all it will act as a medial rotator. On the other hand it may be paralysed but contracted, in which case it will produce a fixed medial rotation deformity which will be a handicap to the patient unless it too is corrected by a rotation osteotomy. That this mechanism exists can easily be demonstrated at the time of operation, and the result is improved if it is allowed for by combining 50 degrees of lateral rotation of the lower fragment with the adduction. The neck of the femur is unsuitable for this type of osteotomy, which should be carried out as high as possible in the shaft: although this does not produce such a neat appearance radiographically it has the advantages of allowing angulation and rotation at the same site. Since the correction of angulation and rotation must be carried out accurately according to a previous assessment, the osteotomy must be fixed with a plate and four screws.

Before any osteotomy is undertaken the deformity of the hip must be corrected and full abduction must be obtained. This is done most satisfactorily by gradual reduction on a frame. This reduction will ensure complete stretching of the adductor muscles, which

FIG. 3
Case 1—True paralytic dislocation of the left hip in a boy of nine.

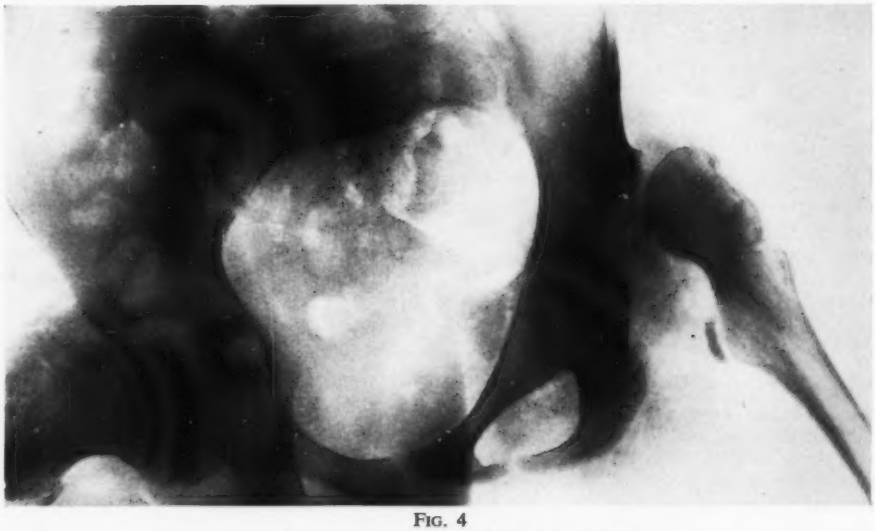

FIG. 4
Case 1—Greatest correction obtained on a frame.

may be contracted. Sometimes the adductor contracture will be such that a tenotomy will be necessary before adequate correction can be obtained. If it is necessary to get full medial rotation, as is sometimes the case, this can be done by serial plaster spicas applied with the

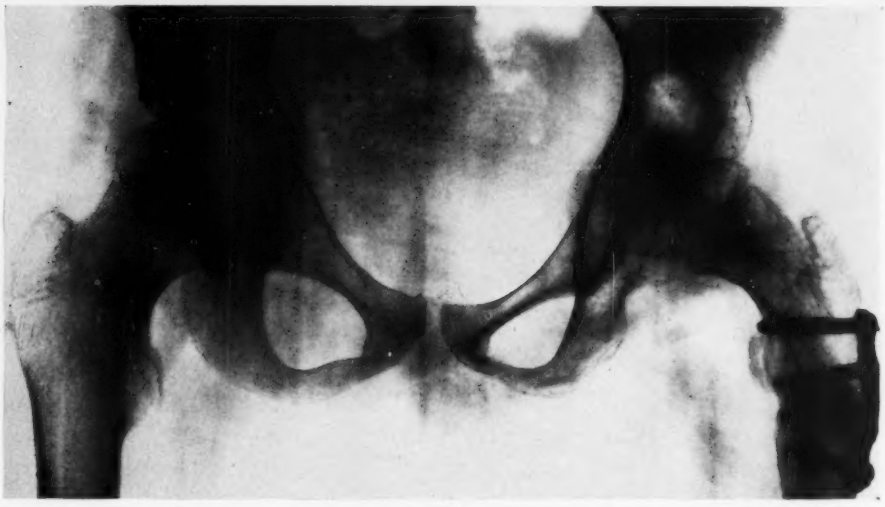

FIG. 5
Case 1—Condition after rotation-adduction osteotomy.

aid of anaesthesia, although force must never be used as the bones are often brittle. Unless a satisfactory position can be obtained in this way it is useless to proceed, but it is worth bearing in mind that an adduction osteotomy produces relative lengthening of the adductor muscles, and fortunately this often means that the ultimate position will be better than might have been expected from the preliminary manipulations.

Fortunately, in paralytic dislocations of the hip, unlike congenital dislocation, the limbus is not inverted and there is no intra-acetabular obstruction. For the limbus to be inverted there must, of necessity, be oft-repeated active flexion and extension of the dislocated hip. This active movement being impossible in the paralysed limb, the limbus remains everted.

Examples of this type of dislocation and its correction are shown in Figures 3 to 8.

ILLUSTRATIVE CASES

Case 1 shows the true paralytic dislocation of the left hip in a boy of nine. His right leg was normal. Attempts to reduce the dislocation by gradual abduction on a frame failed even after an adductor tenotomy had been carried out (Fig. 4), and a suitable position could be obtained only by putting the hip into full medial rotation under anaesthesia and immobilising it in this position in a plaster spica for two weeks before carrying out a rotation-adduction osteotomy (Fig. 5).

Case 2 illustrates a much simpler problem in a girl of ten (Fig. 6). This dislocation could be reduced easily without special manoeuvre (Fig. 7), but when reduced the hip was extremely unstable. This instability was completely overcome by rotation-adduction osteotomy (Fig. 8).

Case 3 concerns the dislocated hips of a child with a meningo-myelocoele (Fig. 9). It is not uncommon in this condition to find that both hips are dislocated. These dislocations are not due to teratological factors, but seem to have the characteristics of a true paralytic dislocation. The dislocation can be easily reduced by abduction on a frame followed by full medial rotation in plaster, the position being maintained by rotation-adduction osteotomy (Fig. 10).

POSTURAL PARALYTIC DISLOCATION

This poses a very much more difficult problem. The dislocation results from obliquity of the pelvis. This obliquity may be caused by factors above or below. When the cause lies above it is probably a structural scoliosis which is likely to be progressive, and even if it can

FIG. 6
Case 2—True paralytic dislocation of the hip in a girl of ten.

FIG. 7

FIG. 8

Case 2. Figure 7—Radiograph showing the hip reduced. Figure 8—After rotation-adduction osteotomy. The hip is now stable.

FIG. 9
Case 3—True paralytic dislocations due to a meningocoele.

FIG. 10
Case 3—After reduction on a frame and rotation-adduction osteotomies.

be corrected it is most unlikely that the correction can be maintained. In such unfavourable circumstances (Fig. 11) it is better to leave the dislocation untreated.

But it must be borne in mind that even if the obliquity is due to factors below, there will always be a scoliosis, and if this has been in existence long enough it will develop structural and irreversible changes. This type of secondary structural scoliosis will not in itself be

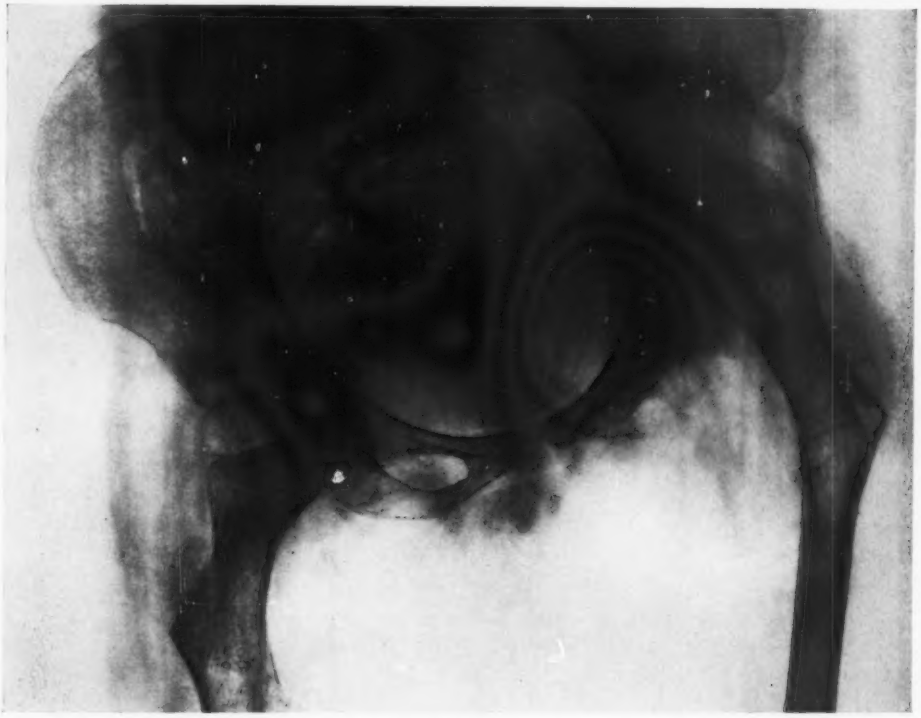

FIG. 11
Pelvic obliquity and subluxation of the left hip resulting from a structural scoliosis.

progressive, and, if the factors causing it—namely those that are producing the pelvic obliquity from below—are corrected, then increase in the curvature will be arrested and it is likely that some correction will take place.

The usual cause of pelvic obliquity produced from below is an abduction-flexion contracture of one hip with consequent dislocation of the other (Fig. 12). It is unfortunate that the hip which dislocates is usually the less severely affected of the two. The size and texture of the two femurs shown in Figure 12 indicate that this is the case here. This makes it a matter of great importance that the deformity shall not be allowed to persist.

Although the dislocation results from the excessive contractures of the opposite hip, use can be made of these contractures to produce stability of the joint, in just the same way as a contracture of the calf is the greatest help in producing stability in an otherwise paralysed limb. It is important that the contractures are not ruthlessly destroyed by soft-tissue release operations but rather that the deformities are corrected by osteotomy to the exact amount of angulation estimated beforehand. So far as the abduction contracture is concerned this can easily be corrected by osteotomy, but only a small amount of flexion can be corrected in

FIG. 12

Case 4—Pelvic obliquity resulting from abduction-flexion contracture of the right hip. This has caused a subluxation of the left hip. The different texture of the two femora indicates that the paralysis was less on the left than on the right.

FIG. 13

Case 4—After correction of the deformity on the right by osteotomy. The position of the left hip is much improved.

FIG. 14
Case 5—Appearance like that in Figure 12; the paralysis was almost complete on both sides.

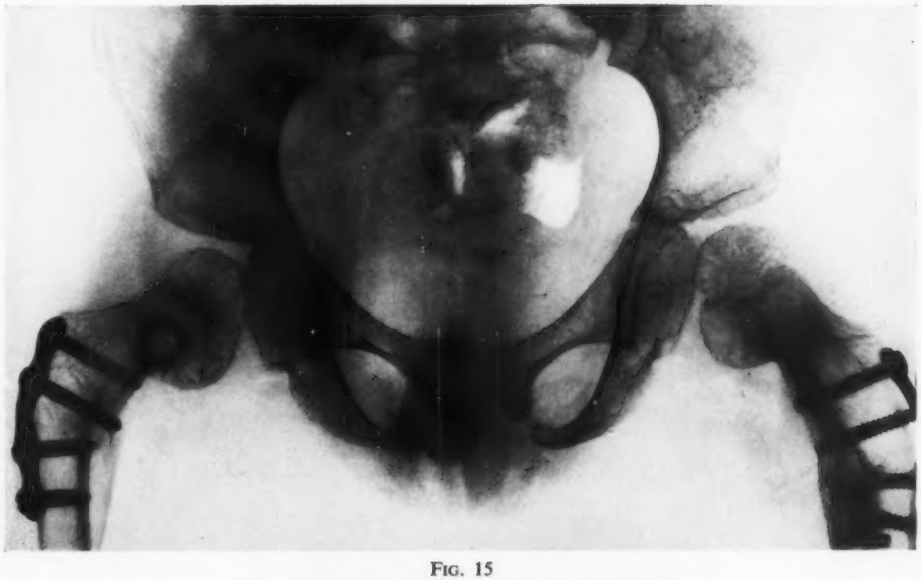

FIG. 15
Case 5—After bilateral rotation-adduction osteotomies.

this way. When the flexion contracture is excessive it must be corrected by a soft-tissue slide, but great care must be taken to see that it is not overcorrected even at the risk of the operation's having to be repeated later. A small flexion contracture can be of great value in a paralysed limb, for it is the only available means of swinging the limb forwards; in this respect it is infinitely better than any external apparatus.

ILLUSTRATIVE CASES

Case 4 is one in which a flexion-abduction contracture on the right had produced pelvic obliquity so that the left hip, which was on the less paralysed side, was subluxated (Fig. 12). Correction of the deformity on the right by means of an osteotomy has greatly improved the position on the left (Fig. 13).

Case 5 concerns the hips of a child of six with almost complete paralysis of both legs and an abduction contracture of the right hip causing dislocation of the left (Fig. 14). In view of the extensive paralysis rotation-adduction osteotomies were carried out on both hips (Fig. 15).

DISCUSSION OF RESULTS

It is sometimes questioned whether the correction of dislocation in such hips is of more than academic interest, or whether it is of some practical value to the patient. Only five of the eight patients treated have been illustrated here. The other three have been similar and it can be said with certainty that these patients have benefited from the operation in consequence of the improvement—however slight—in the stability of the hips. The patient in Case 1 is now able to discard his caliper for long periods, and the shortening of his leg, though still considerable, is less. In Case 2 the hip is no longer slipping in and out with every stride, and presumably the risk of subsequent arthritis and pain have at least been reduced. The patients in Cases 4 and 5 were children who at the ages of five and six years old respectively had never walked despite prolonged treatment since the onset of paralysis. Patient 4 can now use her left leg with only a below-knee iron and with a caliper on the right leg, and can walk with sticks. Patient 5 can, with two calipers aided by slight bilateral flexion contractures of the hips, walk without sticks across the gymnasium, but usually uses sticks. Despite the lateral rotation osteotomies he is, four years after operation, beginning to walk with the limbs turned medially.

From these few illustrative cases it seems that when correction of a subluxation or dislocation can be obtained easily by simple positioning of the limb the manoeuvre is well worth while, but if the reduction cannot be obtained easily it is better that it should not be attempted: the bones in such cases are often very fragile and any use of force is likely to lead to trouble. When the pelvic obliquity is due to spinal deformity it is unlikely that treatment will be of value.

SUMMARY

1. Two types of paralytic dislocation of the hips are discussed.
2. The mechanics of dislocation and the methods of reduction are described, with emphasis on the importance of maintaining or increasing stability where possible.

I am indebted to Professor J. Trueta for his advice with this paper, and to Mr J. G. Taylor of Norwich for permission to describe Case 3.

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A FOLLOW-UP STUDY OF ILIOPSOAS TRANSFER FOR HIP INSTABILITY

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This paper is a critical analysis of patients who have had a transfer of the insertion of the iliopsoas muscle from the medial to the lateral side of the femur in complete paralysis or weakness of the abductor muscles of the hip. A study of fifty patients operated upon over a period of nine years forms the basis of this analysis.

SELECTION OF PATIENTS

The ideal patient for iliopsoas transfer is one who has isolated hip abductor weakness and, as has been pointed out previously (Mustard 1952), good abdominal muscles, good gluteus maximus, good sartorius, good iliopsoas and good quadriceps muscles. However, we have operated upon patients not having these prerequisites with gratifying results. Age does not seem important—our youngest patient was three and a half years old and our oldest fifty-five.

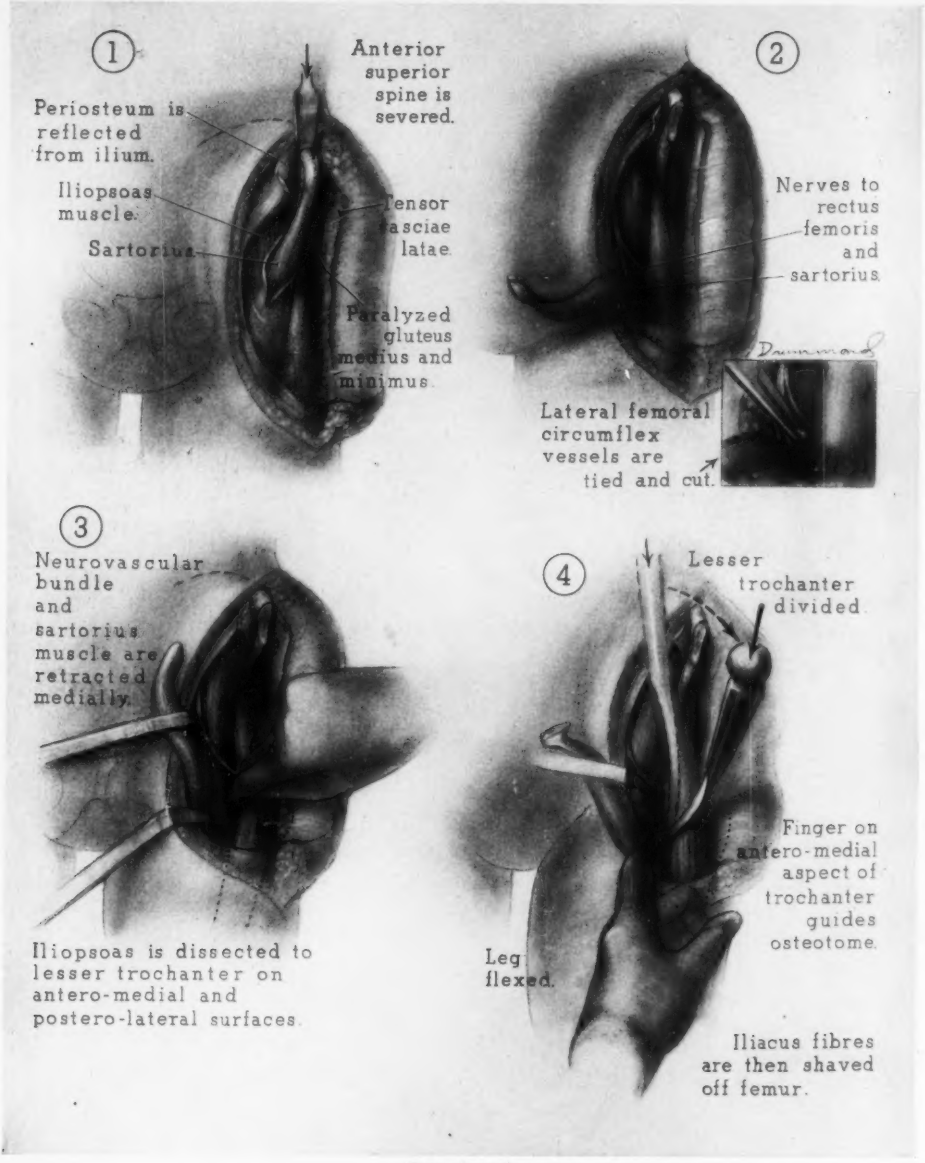
It has been our experience that paralysis of the hip abductors is usually accompanied by varying weakness of the gluteus maximus. Isolated paralysis of the hip abductors is not common, although it does occur. The results of operations upon patients with poor gluteus maximus power have been so satisfactory that we now do not hesitate to recommend the operation for patients having only hip flexion power. The lurch from hip instability is not only disfiguring but gets worse over the years and may lead to pain and subluxation. The subjective symptom of fatigue is often underrated by patients until they appreciate the difference between their condition before and after operation.

We have found it rather difficult to test the iliopsoas muscle, although classically flexion of the hip from 90 degrees to 130 degrees (or the knee to the chest from a right angle) should allow the strength to be assessed. In thin patients it is often possible to feel the tendon of the psoas in extreme flexion. A radiograph to outline the psoas shadow may be useful. It is worth noting that, after transfer of the iliopsoas laterally, patients are able to flex their knee to 70 degrees and occasionally flexion to 90 degrees is possible. The transferred iliopsoas probably assists in flexion in medial rotation after flexion has been initiated by the sartorius.

OPERATIVE TECHNIQUE

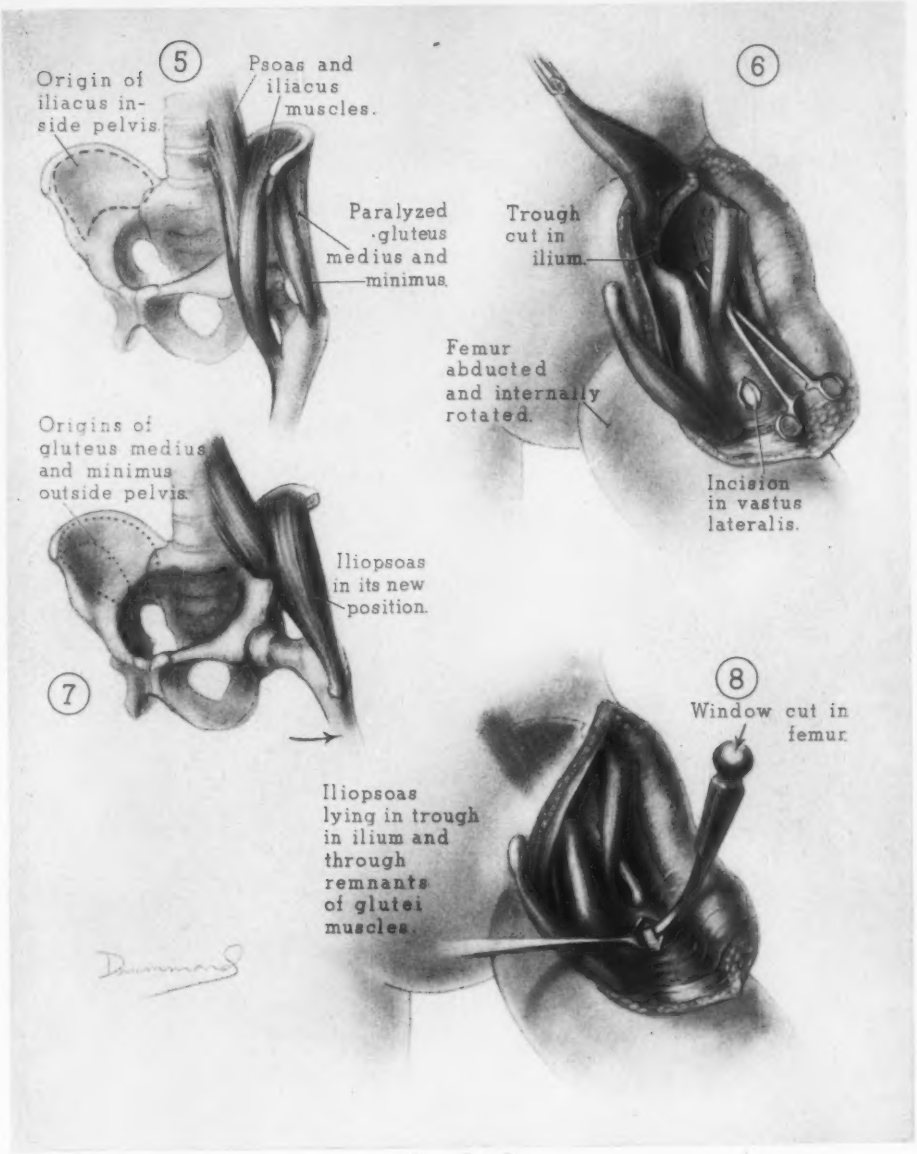
With the patient lying on an ordinary operation table, and slightly tilted to the opposite side, an incision is made just lateral to the crest of the ilium and carried anteriorly for about three inches, but going a little more medially than the usual Smith-Petersen incision, before it is curved distally and posteriorly to divide the tensor fasciae latae about two-fifths of the way down the thigh (Fig. 1).

The plane between the tensor fasciae latae and the sartorius is found and the lateral femoral cutaneous nerve resected. An incision is then made along the crest of the ilium subperiosteally to reflect posteriorly the tensor fasciae latae and the remnants of the gluteal muscles. This incision is carried over the crest to dissect off the attachment of the abdominal muscles until the iliacus is exposed. By subperiosteal dissection, carried down into the pelvis on the lateral side of the iliacus, the anterior superior spine is made to stand out in relief. This is severed, a good portion of bone being taken with the origin of the sartorius; and, by lifting this up, the medial edge of the muscle is easily seen. The sartorius is then lifted and carried downwards and medially, dissection being bold along the lateral border and cautious


1
Anterior superior spine is severed.
Periosteum is reflected from ilium.
Iliopsoas muscle.
Tensor fasciae latae.
Sartorius
Paralyzed gluteus medius and minimus.
2
Nerves to rectus femoris and sartorius.
Lateral femoral circumflex vessels are tied and cut.
3
Neurovascular bundle and sartorius muscle are retracted medially.
Iliopsoas is dissected to lesser trochanter on antero-medial and postero-lateral surfaces.
4
Lesser trochanter divided.
Finger on antero-medial aspect of trochanter guides osteotome.
Leg flexed.
Iliacus fibres are then shaved off femur.

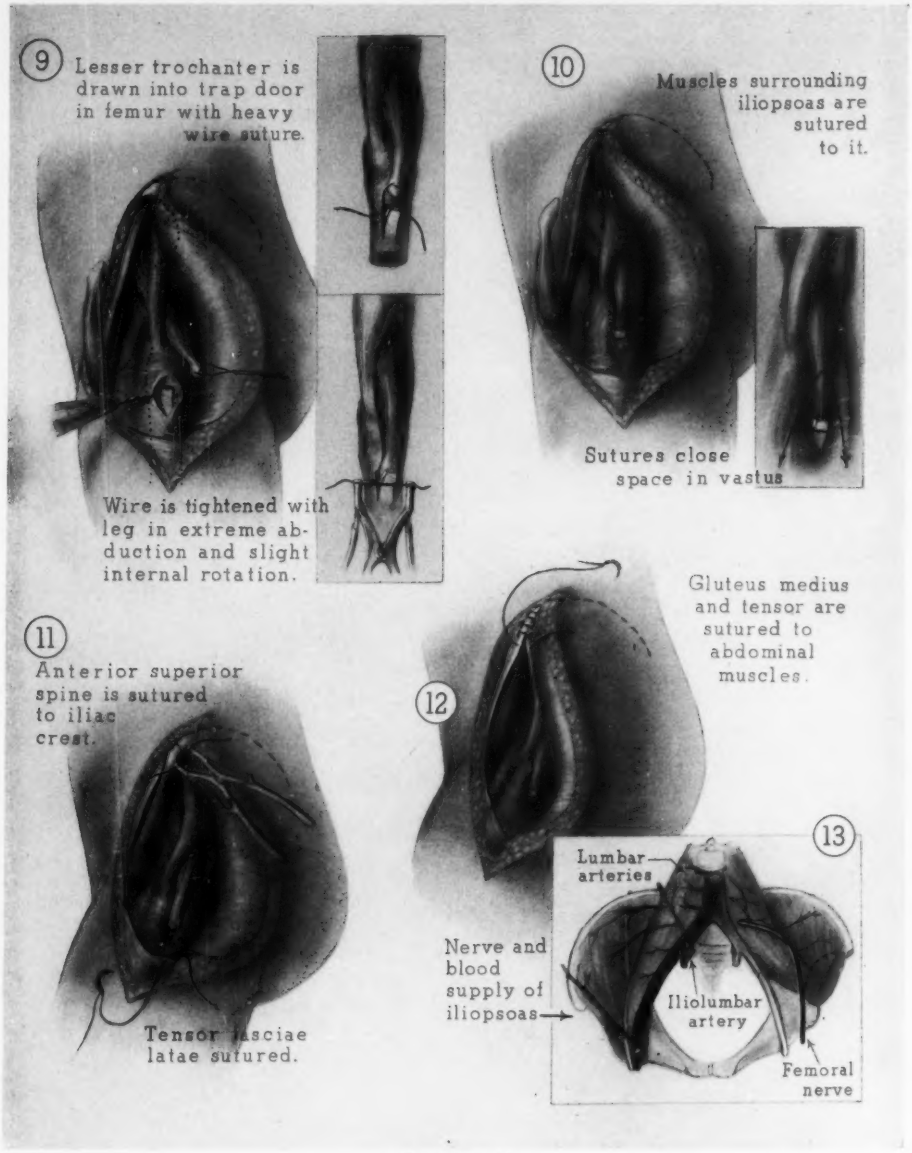
FIGS. 1 TO 4
Stages in the operation.

on the medial border, until the nerve which enters the muscle belly is seen (Fig. 2). This nerve is traced to the femoral nerve, which is identified as it lies on the iliacus, and dissection is carried downwards until the branch of the femoral nerve to the rectus femoris is found. Occasionally the latter has a high origin and this necessitates dissection between it and the femoral nerve before the circumflex vessels can be identified and carefully ligated. Retracting the femoral nerve and the vessels medially allows the top of the lesser trochanter to be


5
Origin of iliacus inside pelvis.
Psoas and iliacus muscles.
Paralyzed gluteus medius and minimus.
6
Trough cut in ilium.
Femur abducted and internally rotated.
Incision in vastus lateralis.
Origins of gluteus medius and minimus outside pelvis.
Iliopsoas in its new position.
7
8
Window cut in femur.
Iliopsoas lying in trough in ilium and through remnants of glutei muscles.

FIGS. 5 TO 8
Stages in the operation.

identified, and a space above and below it is cleared with the finger, as well as the inferior surface of the iliacus (Fig. 3). Occasionally it is a little difficult to distinguish the plane of cleavage between the latter and the rectus femoris. Furthermore, there are often extra attachments of the iliacus to the capsule of the hip joint and the ramus of the pubis. There is a safe plane deep to the fleshy belly of the iliacus which can be dissected downwards until, from the lateral aspect of the iliopsoas muscle, the lesser trochanter can be felt with the stout


9
Lesser trochanter is drawn into trap door in femur with heavy wire suture.
Wire is tightened with leg in extreme abduction and slight internal rotation.
10
Muscles surrounding iliopsoas are sutured to it.
Sutures close space in vastus
11
Anterior superior spine is sutured to iliac crest.
Tensor fasciae latae sutured.
12
Gluteus medius and tensor are sutured to abdominal muscles.
13
Lumbar arteries
Nerve and blood supply of iliopsoas
Iliolumbar artery
Femoral nerve

FIGS. 9 TO 13
Stages in the operation.

psoas tendon inserted into it and the fibres of the iliacus continuing down to their insertion on the linea aspera. At this stage, flexion and lateral rotation of the leg often allow the lesser trochanter to be seen, before it is severed with a curved osteotome. One finger placed on the medial or superficial aspect of the lesser trochanter is used to direct the osteotome to the deep superior edge of the trochanter (Figs. 4 and 5). The trochanter is delivered into the wound and the remainder of the iliacus attached to the linea aspera is sacrificed and shaved off, in

a somewhat tedious part of the operation, but which, with experience, can be carried out reasonably quickly. The key to this part of the operation is to proceed below the nerve to the rectus femoris if it looks as if it will be at all in the way. Once the lesser trochanter with the psoas tendon and the iliacus muscle has been delivered into the wound, the few vessels which enter the muscle in this area can be cleaned off, and this allows the whole of the iliopsoas to be moved into a good position for abduction.

The next stage is to divide the tensor fasciae latae, midway between origin and insertion, so that it may be turned backwards without interfering with the nerve supply. On medially rotating the femur the greater trochanter is easily shown with the vastus lateralis attached distally and the remnants of the gluteus medius and minimus and gluteus maximus proximally. Swinging the iliopsoas sideways and abducting the hip allows the position for the lesser trochanter to be gauged.

A trough is then cut in the wing of the ilium including the base of the anterior superior spine. The trough must be as high and posterior as possible to allow a good line of direction for the iliopsoas muscle (Fig. 6). With the pelvis exposed on both inner and outer sides it is simple to cut this trough, which must be large enough to accommodate the transposed muscle (Fig. 7). Next, after the line of direction of the iliopsoas has been judged, a decision must be made whether it would be wiser to divide the remnants of the abductor muscles and lay the iliopsoas in this gutter, or to split the muscles in such a fashion that the iliopsoas can be pulled through relatively easily (Fig. 8). With the thigh abducted to its fullest extent and slightly rotated medially, and with powerful tension on the tendon of the iliopsoas muscle with the attached lesser trochanter, a site is selected for the insertion, under tension, of the lesser trochanter and the attached iliopsoas into the shaft of the femur. A small window is cut in the femur (Fig. 8) and the lesser trochanter is anchored firmly in this position as shown in Figure 9. The vastus lateralis is sutured to the edges of the psoas tendon (Fig. 10) and the iliacus muscle and any remnants of abductor hip muscles which are present are also sutured carefully to the muscle. The tensor fasciae latae is then repaired and the anterior superior spine anchored firmly to the crest of the ilium (Fig. 11). This may require some flexion of the hip. The tensor fasciae latae and the remainder of the abductor muscles which have been detached from the iliac crest are then resutured to the abdominal muscles and the incision is closed in the usual way (Fig. 12). A hip spica is applied in a position of medial rotation, slight hip flexion and full abduction.

POST-OPERATIVE CARE

At the end of six weeks the hip spica is removed and the patient practises non-weight-bearing abduction and flexion exercises. After a few days the patient is allowed up on crutches, non-weight-bearing, and continues to carry out appropriate exercises until good abduction power is established. Weight bearing with crutches is continued for about six months after the operation in order to eliminate the habit of lurching as much as possible.

ANALYSIS OF RESULTS

These patients are a difficult group to analyse on a broad basis because so many of them have had other procedures. Almost invariably a stabilisation in some form has had to be performed on the foot on the same side. Many patients have had a panarthrodesis and are difficult to compare with those that have a good calf. For this reason a table has been included to show the analysis in some detail (Table I).

A review of the complications after operation shows that most of them have been caused by faults in technique and not by the operation itself. The patient whose quadriceps was weakened from good to poor is rather disturbing, and in retrospect we feel certain that this was due to the femoral nerve's being embedded in the iliacus muscle and stretched when the

TABLE I

DETAILS OF PATIENTS SUBJECTED TO ILIOPSOAS TRANSFER

Case number	Age at operation (*years*)	Date of operation	Years after poliomyelitis	Fatigue	Walking distance	Lurch
1	15	1949	4	Less	Increased	Slight
2	12	1949	9	Less	Increased	Slight
3	11	1950	6	Less	Increased	Moderate
4	39	1950	38	Much less	Greatly increased	Slight
5	12	1950	11	Less	Greatly increased	Moderate
6	8	1950	7	Less	Increased	Present—less
7	13	1950	2	Less	Increased	—
8	9	1950	8	Less	Increased	Present—less
9	8	1951	3	Less	Increased	None
10	24	1951	10	Less	Increased	Slight
11	20	1951	—	Same	Increased	Present—less
12	12	1951	11	Less	Increased	Present—less
13	11	1952	4	Much less	Increased	None
14	5	1952	3	Less	Increased	Fair
15	13	1952	8	Less	Increased	Present—less
16	19	1953	18	Much less	Increased	Less
17	16	1953	16	Much less	Increased	Slight
18	8	1953	2	Less	Increased	None
19	10	1953	7	Less	Increased	None
20	30	1953	3	Unchanged	Unchanged	Yes
21	17	1953	2	—	—	—
22	55	1954	54	Less	Increased	Fair
23	10	1954	3	Less	Increased	Present—less
24	6	1954	5	Much less	Marked increase	Mild
25	8	1954	7	Less	Increased	Present—less

TABLE I

DETAILS OF PATIENTS SUBJECTED TO ILIOPSOAS TRANSFER

Hip stronger	Flexion (*degrees*)	Abduction		Gluteus maximus	Trendelenburg. Negative or positive	Other procedures	Complications
		Before	After				
Yes	70	Nil	Normal	Fair	Negative	Triple arthrodesis; transfer to heel	—
Yes	70	Trace	Normal	Poor	Negative	Ankle fusion; epiphysial arrest	—
Yes	80	Nil	Good	Fair	Positive	Triple arthrodesis; tendon transfer	—
Yes	90	Nil	Normal	Good	Negative	Panarthrodesis, tendon transfers: tenodesis	—
Yes	60	Nil	Normal	Poor	Negative	—	—
Yes	60	Fair−	Good	Good	Negative	Transfer to heel, triple arthrodesis, epiphysial arrest	—
Yes	90	Fair−	Normal	Good	Negative	Transfer to dorsum	—
Yes	15	Poor	Fair—good	Fair	Positive	Pantalar arthrodesis, epiphysial arrest	—
Yes	—	Poor	Normal	Poor	Negative	Tendon transfer heel, epiphysial arrest	—
Yes	70	Trace	Normal	Good	Positive	—	Osteomyelitis of lesser trochanter
Yes	90	Nil	Fair+	Fair+	Positive	—	—
Yes	90	Poor	Normal	Good	Negative	Pantalar arthrodesis, femoral shortening, epiphysial arrest	—
Yes	80	Nil	Normal	Good	Negative	Pantalar arthrodesis	—
Yes	70	Nil	Fair	Poor	—	Tendon transfer heel—subtalar arthrodesis	—
Yes	70	Fair−	Good	Good	Positive	Triple arthrodesis, tendon transfer of the foot, epiphysial arrest	—
Yes	60	Poor	Good	Good	Negative	Pantalar arthrodesis, femoral shortening	—
Yes	50	Trace	Good	Good	Positive	Panarthrodesis	—
Yes	70	Poor	Good	Good	Some negative drift	Tendon transfer in foot	—
Yes	80	Poor	Normal	Normal	Negative	Transfer to dorsum of foot	—
No	45	Nil	Nil	Nil	Positive	Panarthrodesis	Poor result, iliopsoas only fair
—	—	—	—	—	—	Panarthrodesis	—
Yes	60	Nil	Fair	Fair	Positive	Transfer in foot	Weakened quadriceps
Yes	60	Poor	Normal	Good	Negative	Transfer to heel, subtalar arthrodesis	—
Yes	60	Poor	Normal	Fair	Negative	—	—
Yes	60	Poor	Good	Fair	Negative	Transfer to heel	—

TABLE I—*continued*
DETAILS OF PATIENTS SUBJECTED TO ILIOPSOAS TRANSFER

Case number	Age at operation (*years*)	Date of operation	Years after poliomyelitis	Fatigue	Walking distance	Lurch
26	12	1954 (myelomeningocele)	—	Much less	Improved	Present—much less
27	5	1955	4	Less	Increased	Slight
28	22	1955	4	Less	Increased	None
29	13	1955	11	Less	Increased	Yes
30	11	1955	2	Less	Increased	Present—slight
31	3½	1955	1	Less	Increased	Present—less
32	13	1955	9	Less	Increased	Present—less
33	8	1955	6	Less	Increased	Slight
34	12	1955	8	Less	Increased	Less
35	8	1955	7	—	—	—
36	7	1955	6	Less	Increased	Slight
37	9	1955	8	Less	Increased	Present—less
38	5	1955	5	Less	Increased	Slight
39	23	1955	21	Less	Increased	Fair
40	12	1956	3	Less	Increased	Slight
41	12	1956	3	Less	Increased	Fair
42	7	1956	5	Less	Increased	Less
43	22	1956	21	Less	Unchanged	Less
44	8	1957 (myelomeningocele)	—	Operation done for hip subluxation; now stable.		
45	4	1957	4	Less	Increased	Slight
46	15	1957	8	Too early to assess	—	Much less
47	6	1957	4	Too early to assess	—	—
48	10	1957	6	Unchanged	—	Less
49	27	1958	5	Less	—	Less
50	9	1958	5	Too early to assess	—	—

TABLE I—*continued*
DETAILS OF PATIENTS SUBJECTED TO ILIOPSOAS TRANSFER

Hip stronger	Flexion (*degrees*)	Abduction		Gluteus maximus	Trendelenburg. Negative or positive	Other procedures	Complications
		Before	After				
Yes	90	Nil	Fair−	Nil	Negative	Panarthrodesis	—
Yes	50	Nil	Good	Poor	Negative	Calcaneal tenodesis	—
Yes	60	Nil	Good	Good	Positive	Tendon transfer to dorsum of foot	Sartorius re-sutured to A.S.P.
Yes	45	Nil	Fair	Fair	Positive	Sympathectomy, tendon transfer, triple arthrodesis, epiphysial arrest	—
Yes	70	Trace	Normal	Good	Negative	Transfer to heel	—
Yes	60	Poor	Normal	Good	Negative	Transfer to heel	—
Yes	70	Poor	Fair−	Fair	Positive	Tenodesis, tendon transfer, epiphysial arrest, osteotomy first metatarsal	Iliopsoas only fair before operation
Yes	40	Nil	Fair	Nil	Positive	—	—
Yes	20	Nil	Good	Nil	Negative	Panarthrodesis	Fracture through fixation site February 1956, difficult to assess functional result as yet
—	—	Poor	—	Poor	—	Tenodesis, sympathectomy, Green arthrodesis	—
Yes	50	Trace	Good	Good	Some negative drift	Fasciotomy, tenodesis, AV fistula	—
Yes	40	Poor	Fair−	Good	Negative	Tenodesis	—
Yes	60	Nil	Good	Nil	Negative	AV fistula, anterior tenodesis	—
Yes	45	Nil	Fair—good	Good	Positive	Panarthrodesis	—
Yes	90	Poor	Normal	Fair	Slightly positive	Lambrinudi	—
Yes	70	Nil	Fair	Nil	Negative	Bilateral triple arthrodesis	—
Yes	80	Nil	Good	Normal	Negative	Osteotomy femur. Will require triple arthrodesis	—
Yes	30	Nil	Fair+	Poor	Positive	Lumbar sympathectomy, calcaneal tendon lengthening. Jones' suspension, femoral shortening	—
—	—	—	—	—	—	Patient wears a brace	—
Yes	90	Nil	Good	Fair	Negative	Below-knee brace	—
Yes	90	Trace	Good	Good	Slightly positive	Triple arthrodesis	—
—	60	Nil	Good	Poor+	Slightly positive	Below-knee brace	—
Yes	90	Fair	Good	Good	Positive	Transfer to heel	—
Yes	30	Nil	Fair	Nil	Negative	Pantalar arthrodesis	—
—	40	Trace	Normal	Good	Negative	(Drop foot)	—

muscle was transferred. Usually the nerve can be readily seen and freed from the iliacus as this muscle is transferred laterally. Although this patient has considerable improvement in her hip certainly the quadriceps has become weakened. In one other patient there was a temporary weakening of the quadriceps muscle. In the patient on whom the operation can only be called a failure the iliopsoas was not good and there was no other active muscle at the hip; this implies that only a strong normal muscle should be transferred.

DISCUSSION

Actual power of abduction is not the goal of the operation; we are seeking holding power of the pelvis to the femur against body weight. It is for this reason that the adherence of the bulky short-fibred iliacus to the trough in the ilium is important. The tendon of the psoas muscle with the lesser trochanter provides a handle for rerouting the iliacus through the pelvis. The range of abduction is occasionally startling and we feel that this is probably due to the associated increased neck valgus when paralysis has occurred in childhood and the more distal insertion of the tendon. Varus osteotomy of the neck of the femur should precede transfer in paralytic dislocations. We have one such case and Fleming (1958) reported three cases.

Patients who have lurched for many years may continue to do so even though the pelvis holds when weight is taken on the affected leg. The lurch, however, has been uniformly lessened if a normal muscle has been transferred. A few patients have appeared not to have a normal muscle at operation, the results of which have not been as good as expected. Most patients who have a trace of, or poor, power in their hip abductor mechanism are deferred until four years after the onset of the paralysis. Absent power of abduction is an indication for operation as early as two years after the attack of poliomyelitis.

Patients whose results could only be considered poor to fair at the end of six months to one year often improve remarkably in the following years. One of our earlier patients, when brought back for follow-up nine years later, was considered to have a good result, whereas the rating at two and three years after operation was only fair. This is to be expected if the muscle was of normal power and satisfactorily transferred as a lateral stabiliser of the hip. It is our feeling that this muscle transfer should be effective in conditions of hip instability other than poliomyelitis. Arthroplasty of the hip in which the stabilising muscles have atrophied beyond any recovery, certain cases of congenital dislocation of the hip, spastic paralysis, and myelomeningocele are examples. Two of our patients were in the latter group.

SUMMARY

Fifty cases of iliopsoas transfer have been reviewed. The indications for operation, operative technique and post-operative care have been described. It seems that the iliopsoas muscle transferred laterally through the ilium acts as a better hip stabiliser than it does in its original position. The operation should not be undertaken by a casual operator and should be performed first in the post-mortem room.

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THE TREATMENT OF UNREDUCED CONGENITAL DISLOCATION OF THE HIP IN ADULTS

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In their review of the late results of the treatment of congenital dislocation of the hip Müller and Seddon (1953) commented that between the ages of twenty-three and thirty-three years nearly half the previously satisfactory joints become troublesome in one way or another. When reduction of the dislocation has been achieved, the problem usually becomes one of treatment of a degenerative arthritis of the hip. When a dislocation has remained unreduced, or has recurred after treatment in childhood, the problem is a more complex one in which instability of the hip, shortening of the leg and spinal deformity are important. Pain in the hip is usually, but not invariably, associated with the onset of degenerative arthritis, and it is the onset of pain which drives these patients to seek surgical relief. Although it is undoubtedly true that many adults with a persistent dislocation of the hip pass their lives without demanding orthopaedic treatment, most are severely disabled, and even in the absence of arthritic changes their difficulties increase with age. It is against this background of a progressive locomotor disturbance that the results of surgical treatment must be judged.

MATERIAL

From an examination of the records of the Royal National Orthopaedic Hospital and of ten of the London undergraduate teaching hospitals, sixty-two patients over the age of twenty-one were found to have received operative treatment for an unreduced congenital dislocation of the hip. Patients with subluxation or minor degrees of dislocation were disregarded, as were the subluxated hips treated for osteoarthritic changes in patients with a dislocation on the other side. At the Royal National Orthopaedic Hospital it was possible to carry the investigation back for more than thirty years, but elsewhere the figures relate only to the post-war period. The number of patients subjected to operation is surprisingly small; indeed at three of the teaching hospitals no operation of this type has been performed in the last ten years. Since dislocation of the hip in adults is not uncommon, it appears probable that most of the patients, reconciled to their disability from early life, do not demand active treatment. Perhaps another factor of equal importance is a general dissatisfaction amongst orthopaedic surgeons with the results of operations for this condition.

With the co-operation of the records officers in many hospitals, forty patients were traced for review. The relatively complex methods of assessment of hip function described by Shepherd (1954*a*) and the indices of hip mobility suggested by Gade (1947) appear to have little place in the assessment of patients handicapped as severely as these, and a simple assessment of pain, disability and hip movement has therefore been devised:

Pain—0=none at any time; 1=slight and occasional pain on walking; 2=moderate pain on walking, none at rest; 3=severe pain on walking, pain at night, requiring analgesics.

Limitation of activity—0=full activity; 1=unable to walk long distances, or to play games; 2=able to get out of doors only for essential activities; 3=confined to the house.

Range of movement—None; poor=30 degrees flexion only; moderate=60 degrees of flexion with slight lateral and rotational movement; good=90 degrees of flexion, with more than half the normal range of abduction and rotation.

In assessing the pre-operative state of the patient it has been necessary to rely upon the notes made at the time, and the patient's own memory. Although the latter is often clouded

by prejudice and by the passage of time, it probably remains the more valuable standard. For most patients it was also possible to record the presence of spinal deformities, and of associated back pain, the amount of leg shortening, both real and apparent, and the evidence of hip instability recorded by Trendelenburg's test. For all these patients pre-operative radiographs were available, and radiographs were also taken at the time of review.

In making a final assessment of the value of the treatment the patient's own views must naturally demand considerable attention. Of greatest importance is the relief of pain in the hip, because this is usually the symptom for which treatment is sought. Increased capacity for physical activity after the operation is also valued highly, but an academic assessment of the range of joint movement often has little relation to the clinical problem. It must not be forgotten, however, that these patients presented themselves for treatment because the disability was increasing, and we must accept the views of many of them that without the operation they would soon have become bedridden.

CONDITION BEFORE OPERATION

In all the patients the diagnosis of congenital dislocation of the hip was made in childhood. No information about its treatment, except that given by the patients themselves, was available. Seven patients had been treated by open operation, and in four of these a shelf operation had been performed. Most of the others were treated in plaster after closed reduction of the dislocation, but two patients had no treatment of any kind during childhood. Very few were disabled during childhood, most played games and were fully active until their early twenties, when the onset of symptoms was often related to pregnancy or childbirth. Since these patients were not under continuous supervision, but sought relief for a specific disability, the age at which the first operation was performed is of some significance (Table I).

TABLE I

AGE AT TIME OF OPERATION

Age at operation (*years*)	21–30	31–40	41–50	51–60
Number of patients	5	20	14	1

There were twenty-one patients with dislocation of only one hip, and nineteen with dislocation of both hips. In eight of the latter group both hips were painful and required operative treatment, and in one other patient an arthroplasty (performed too recently to be included in the present review) was performed.

The presenting symptom was usually pain in the hip; in seventeen patients this was severe, and present day and night. The onset of pain was associated with limitation of hip movements, and usually with radiographic evidence of a degenerative arthritis. Limitation of activity was often considerable, and seven patients were confined to the house. Most of the difficulty in walking was due to pain, but hip instability appeared to play a part, especially when both hips were affected. In two patients recurrent dislocation of the femur from the false acetabulum was an added indication for operation.

In unilateral dislocation the pre-operative shortening varied between two and three inches. None of the patients had used a raised shoe to compensate for the discrepancy, but occasionally half an inch was added to the heel. Pain in the back with an associated postural scoliosis seldom amounted to more than an occasional discomfort. With an added lordosis, particularly when this was incorrectable, pain was more common, but was only of major importance in patients with a high dislocation of both hips.

CONDITION AFTER OPERATION

Arthrodesis—Fusion of the dislocated hip was attempted either as a primary manoeuvre, or after an arthroplasty or an osteotomy that had failed. The results of the operations in the ten patients in this group are summarised in Table II.

Bony ankylosis was achieved in all but one of the primary operations, and was associated with complete relief of hip pain. Pain in the back was present before operation in two patients: in one the pain was improved thereafter, and in one it was made a little worse. None of the other patients admitted to any back pain, in spite of the uncorrected shortening which remained. Only one patient retained a shoe-raise after the operation.

TABLE II

RESULTS OF ARTHRODESIS

(Ten cases)

Case number	Previous operation	Technique of arthrodesis	Result	Function
Primary arthrodesis				
1	—	Joint excision. No internal fixation	Bony ankylosis	Good
2	—	Ischio-femoral	Bony ankylosis	Good
3	—	Joint excision; trifin nail fixation	Bony ankylosis	Good
4*	—	Joint excision; trifin nail fixation	Bony ankylosis	Good
5	—	Joint excision and osteotomy. Ischio-femoral graft	Bony ankylosis	Limited (knee instability)
6	—	Joint excision; trifin nail fixation	Pseudarthrosis	Limited
Secondary arthrodesis				
7	Replacement arthroplasty	Ischio-femoral	Graft fracture; pseudarthrosis	Poor
8*	Cup arthroplasty	Removal of cup; trifin nail fixation	Fibrous ankylosis	Poor
9	Lorenz osteotomy	Excision of joint. Osteotomy	Fibrous ankylosis	Poor
10*	Replacement arthroplasty	Removal of prosthesis. No internal fixation	Bony ankylosis	Good

* Bilateral dislocation.

(The patient in Case 4 subsequently underwent arthroplasty on the other hip.)

The level of functional activity in these patients is high. One is working as a petrol station attendant and is training to become an amateur parachutist. One, a dressmaker, unable to work for a year before operation, and confined to the house with some pain day and night in the hip, had the hip arthrodesed thirty-five years ago (Figs. 1 and 2). She is still working at the age of sixty-three, and can walk for five miles or more. The only disability to which these patients admit is the difficulty of lacing up shoes and of putting on stockings; none of them uses a stick.

One of the patients with a successful arthrodesis has some difficulty with instability of the knee, which limits her walking. The instability is associated with gross laxity of the medial ligament of the knee, and probably occurred during plaster immobilisation. The patient in

FIG. 1
Case 1—A high posterior dislocation of the right hip giving severe pain in the absence of arthritic changes.

FIG. 2
Case 1—Thirty-five years after arthrodesis of the hip. Function was excellent.

whom arthrodesis was unsuccessful had a further operation upon the hip, but the femur still moves freely. This hip is still painful.

Secondary arthrodesis of the hip was successful in only one patient, giving relief of pain and a high level of activity. One of the three patients in whom the operation failed has a free range of movement, but is pain-free; the other two have fibrous union, with a few degrees of painful movement at the hip.

TABLE III

RESULTS OF CUP ARTHROPLASTY

(Seventeen operations; thirteen patients)

Case number	Result			Subsequent treatment
	Pain	Movement	Activity	
Unilateral dislocation				
11	None	Good	Increased	None
12	Slight	Poor	Unchanged	None
13	None	None	Diminished*	None
14	Slight	Poor	Unchanged	None
Bilateral dislocation: unilateral operation				
8	Severe	Poor	Diminished	1) Revision of arthroplasty 2) Attempted arthrodesis (failed)
15	None	Poor	Increased	None
16	None	Moderate	Increased	None
17	None	Poor	Increased	None
18	Moderate	Moderate	Diminished	None
Bilateral dislocation: bilateral operations				
19	Slight	Good	Unchanged	Repeated revisions
20	Slight	Poor	Diminished	None
21	Slight	Moderate	Diminished	None
22	Severe	Poor	Diminished	Repeated revisions

* Partial sciatic nerve lesion.

Three of the patients in whom arthrodesis was attempted presented with dislocations of both hips. One of these has recently undergone an arthroplasty on the other hip; two have required no treatment yet on the other side. In this small group bony ankylosis of the hip was compatible with good functional activity, without any added difficulty in clearing the ground with the arthrodesed leg (Fig. 3).

Cup arthroplasty—There were seventeen operations upon thirteen patients in this group, and the patients were examined between three and ten years after the operation. The results are indicated in Table III, which is divided according to the number of hips affected and the number of operations performed. It will be seen that five of the patients gained complete

relief of pain and five others admitted to very little pain in the hip. When only one hip was operated upon the relief of pain was followed by an increase in physical activity, regardless of the range of movement. In only one patient was the range of hip movement good, and this

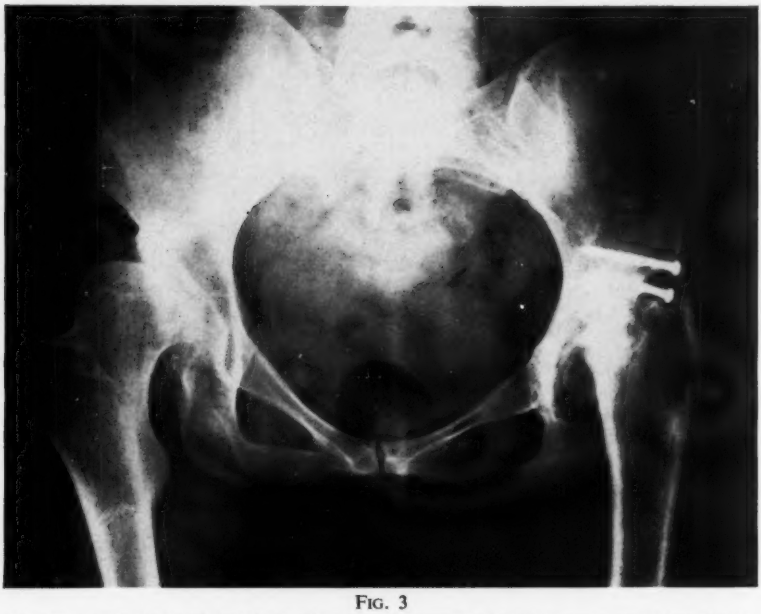

FIG. 3

Case 10—Arthrodesis of the left hip after an acrylic prosthesis had been removed (see Fig. 7). In spite of the instability of the right hip the gait and function are good.

is the only patient in whom the result of the operation was comparable with that of a successful arthrodesis (Figs. 4 and 5). Eight years after the arthroplasty the hip is pain-free and the patient is very active, with a limp which is only just detectable. The results of three of the unilateral operations must be rated as unsatisfactory, two because of the failure to relieve the pain,

TABLE IV

RESULTS OF REPLACEMENT ARTHROPLASTY

(Six operations; five patients)

Case number	Type	Duration of prosthesis (*years*)	Subsequent operation
23	Judet*	5	Awaiting readmission
7	Fitzgerald	4	Arthrodesis (failed)
24	Judet†	5	None. Remains pain-free
10	Judet	4	Arthrodesis (successful)
25	Judet	1	Batchelor's pseudarthrosis

* Bilateral operations. † McMurray osteotomy other side.

and one on account of an incomplete lesion of the sciatic nerve. Although this patient has lost in terms of physical activity, she is pleased with the operation because the pain has been relieved. Shortening in these patients has not been significantly affected by the arthroplasty.

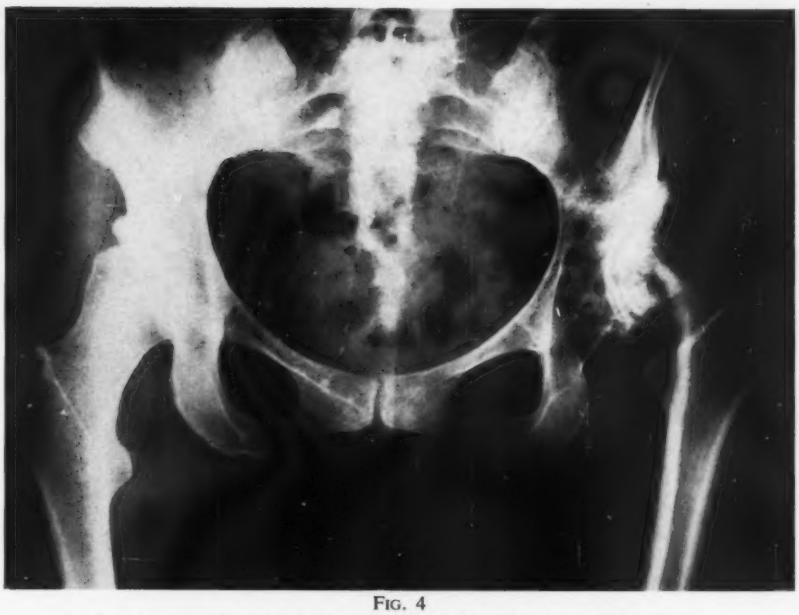

FIG. 4
Case 11—A moderate dislocation of the left hip with osteoarthritic changes.

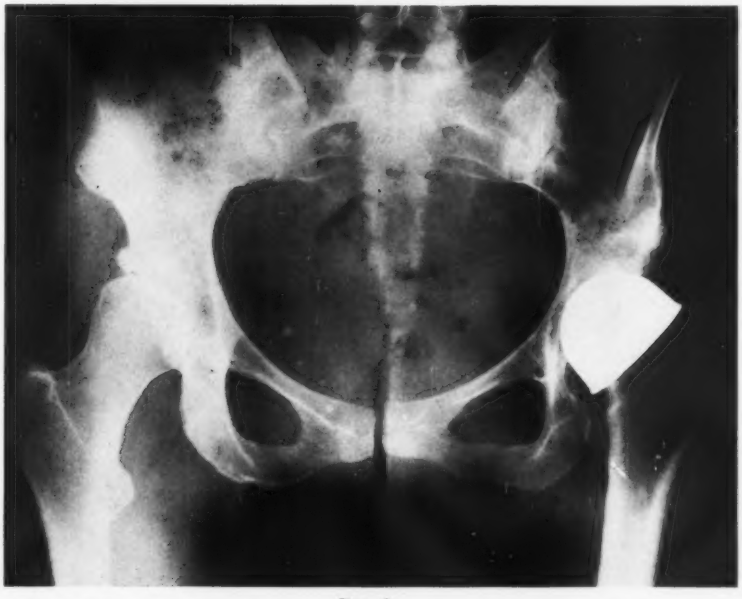

FIG. 5
Case 11—Two years later, after cup arthroplasty. The result is excellent, with a good range of movement, and freedom from pain.

The results of cup arthroplasty on both hips were unsatisfactory. In these patients relief of pain was not followed by an increase in physical activity. It is clear that for a good functional result the hips must not only be relatively pain-free, but also stable and mobile. Only one patient had a good range of movement in both hips and these were grossly unstable (Fig. 6).

One of the advantages claimed for hip reconstruction in the course of an arthroplasty is an increase in stability. Judging from the conversion of a positive Trendelenburg sign into a negative one, this was achieved in only four hips. Two of these were so stiff as to make the sign of doubtful value. Only one of the thirteen patients in this group managed to walk

TABLE V

RESULTS OF HIGH FEMORAL OSTEOTOMY
(Eleven cases)

Case number	Pain	Movement	Activity	Subsequent operations
Lorenz osteotomy				
9	Severe	Poor	Diminished	Arthrodesis (failed)
26	Moderate	None	Diminished	None
27	Moderate	Moderate	Diminished	None
McMurray osteotomy				
24*	Slight	None	Diminished	None
28	Slight	Full	Increased	None
29	Slight	Poor	Increased	None
High subtrochanteric osteotomy				
30	Slight	Moderate	Increased	None
31	Moderate	None	Increased	None
32	Slight	Poor	Diminished	None
33	Slight	Moderate	Unchanged	None
34†	None	None	Increased	None

* Bilateral dislocation. † Spontaneous bony ankylosis.

without a stick, and four required two sticks or crutches for outdoor use. This is in sharp contrast to the patients with successful arthrodeses, none of whom used a stick at any time.

Replacement arthroplasty—Prosthetic replacement of the femoral head was performed in six hips in five patients, and the results are summarised in Table IV. Only one of these operations has been successful, giving a pain-free mobile hip after five years. All the other patients have required revision or are now awaiting readmission to hospital.

A typical result is indicated in Figure 7. The hip gave good service for two years, but then became painful. After four years the prosthesis was removed, and arthrodesis was achieved by decorticating the femur and acetabulum, and reinforcing the hip with an iliac graft (Fig. 2). The final result of the arthrodesis was excellent.

FIG. 6
Case 19—Bilateral cup arthroplasty. Both hips are unstable, but pain is slight.

FIG. 7
Case 10—Deterioration of the hip after a Judet arthroplasty on the left. The acetabulum is ballooned and irregular, and the hip very painful.

Osteotomy of the femur—A number of different osteotomies of the femur have been performed, and it is difficult to compare the results of procedures carried out at varying levels in the femur. In assessing the results it is important to remember that the presenting symptom was one of pain, although in some cases correction of a hip deformity was also to be expected after bone division.

High osteotomies, either of the Lorenz, McMurray or subtrochanteric type, were undertaken in eleven patients, in all cases on one side only. The results are indicated in Table V. These operations were disappointing in the relief from pain that they afforded, and they were often followed by a surprising loss of movement in the hip. Indeed there were three patients with a fibrous ankylosis after osteotomy, and the most successful result was in a patient whose hip had progressed spontaneously to a bony ankylosis (Fig. 8). Two of the Lorenz osteotomies were performed more than thirty years ago. The way in which the lower

FIG. 8
Case 34—Spontaneous bony ankylosis of a dislocated right hip after a subtrochanteric osteotomy.

fragment takes part in the formation of a new joint is indicated in Figure 9. This hip is painful and unstable but has a moderate range of movement. When it is remembered that this group of patients consisted almost entirely of those with dislocation of only one hip, the results must be regarded as unsatisfactory.

Low osteotomy of the Schanz type with a wide angle of abduction, sometimes combined with excision of the head of the femur (producing Batchelor's pseudarthrosis) was performed on nine limbs in seven patients, and the results are indicated in Table VI. Complete relief of pain was seldom obtained, but most patients reported some improvement. All these patients retained a good range of passive movement but most of them found difficulty in flexing the hip actively. Few of them found their physical activities increased after the operation, and whereas the hip was often more stable as judged by Trendelenburg's sign the gain in stability was seldom noticed by the patient.

A typical result can be seen in the radiographs in Figures 10 and 11. The Schanz osteotomy on the left is almost pain-free; the Batchelor's pseudarthrosis is moderately painful. Both hips have a good range of movement, and the patient is a little more active than before her operations.

TABLE VI

RESULTS OF LOW FEMORAL OSTEOTOMY

(Nine operations; seven patients)

Case number	Pain	Movement	Activity	Subsequent operations
Schanz osteotomy				
35	Slight	Good	Unchanged	None
36*†	Slight	Good	Increased	None
Batchelor osteotomy-resection				
37*	None	Moderate	Unchanged	None
36*†	Moderate	Good	Increased	None
38	Slight	Good	Unchanged	None
25*†	Moderate	Good	Unchanged	Obturator neurectomy
39*	None	Good	Increased	None
40	Slight	Good	Unchanged	Required revision

* Bilateral dislocation. † Bilateral operations.

DISCUSSION

The problems which face the patient with an unreduced congenital dislocation of the hip are those of instability, with an associated difficulty in walking, a painful degenerative arthritis, a short leg and a postural scoliosis. If the dislocation is bilateral, the difficulties in walking are more than doubled, and a lumbar lordosis, in time becoming fixed, may be present. These two groups of patients present rather different problems, and can usefully be considered separately.

Unilateral dislocation—Arthrodesis has proved a most satisfactory primary procedure, giving a stable limb, a pain-free ankylosis, a gait often indistinguishable from normal, and good function. Arthrodesis of the hip can be achieved, even in the high dislocation (Watson-Jones and Robinson 1956) in a high proportion of cases, and the method to be used depends largely upon the personal preference and experience of the surgeon. As a salvage procedure after an arthroplasty, however, it is less satisfactory, because bony ankylosis is seldom achieved. The problem resembles that of the failed arthroplasty for osteoarthritis, in which only a small proportion of bony ankyloses can be obtained.

Cup arthroplasty in the unilateral dislocation may well yield the occasional brilliant result, but the operation entails a longer convalescence, and a less certain result. Even if pain is completely relieved, the range of movement is often disappointing. There is little advantage in a mobile hip, when the other hip is normal, unless the operation has achieved 50 or 60 degrees of flexion. Two features of the congenitally dislocated hip make the successful arthroplasty difficult: an anteverted femoral neck, which may require a rotation osteotomy,

and a shallow acetabulum which requires extensive remodelling. Even in the most successful arthroplasty an element of instability and uncertainty about the future must remain.

Smith-Petersen (1948) regarded cup arthroplasty as a most satisfactory procedure for the dislocated hip, partly because of the acetabular reconstruction, and the consequent gain in stability. Stinchfield and Carroll (1949) and Merle d'Aubigné (1952), each with a short period of review, found the operation a good one, although Merle d'Aubigné incurred a high incidence of post-operative dislocation in an attempt to gain length in the leg. In a wider review of cup arthroplasty, Shepherd (1954*b*) found twenty-eight patients in whom the operation had been performed for a congenital dislocation of the hip. The results in these patients, four excellent, six good and eighteen fair or poor, do not differ greatly from those in the present series.

FIG. 9

Case 27—Bilateral dislocation thirty-two years after a Lorenz osteotomy has been performed on the right side, showing the formation of a new joint by the lower fragment.

Replacement arthroplasty appears to have no place in the treatment of the dislocated hip. Although the failure in this series was largely due to the use of a head of unsuitable material, it is difficult to imagine that the extensive acetabular reconstruction which is necessary in these patients is compatible with a good result, even if a more suitable prosthesis were used.

The bifurcation osteotomy, which is poorly represented in this series, was described by Lorenz (1919, 1923) as a palliative procedure for severe pain. Although about sixty operations had been performed by 1923, details of Lorenz's results have not been given, and no large series of operations has since been published. Reich (1925) reported five cases in children in which the results had been satisfactory, but in the discussion which followed his paper there was a general impression that these hips became stiff. From the limited experience afforded by the present review, this is confirmed.

The results of the other high femoral osteotomies are also disappointing, and their value lies more in the correction of deformity than in the relief of symptoms. Müller and Seddon (1953) found fourteen hips in which osteotomies had been performed after the age of twenty,

FIG. 10
Case 36—High dislocation of both hips, with arthritic changes on the right.

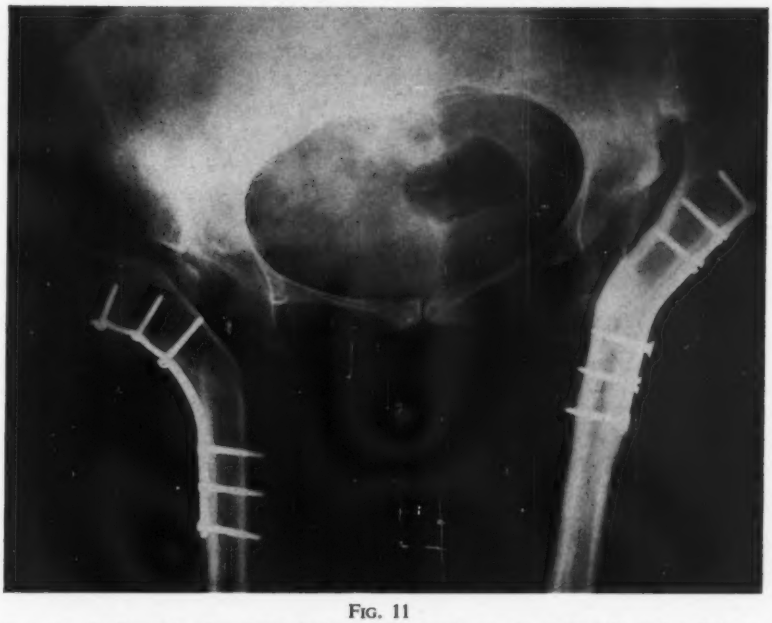

FIG. 11
Case 36—Radiograph after Batchelor's pseudarthrosis on the right side and a Schanz osteotomy on the left. Both hips are still painful, but fairly mobile.

none with a good result. McMurray's displacement osteotomy may have a limited place in the treatment of a low dislocation which is relatively stable, provided a good range of movement remains. If the hip is unstable a McMurray osteotomy, by increasing the valgus at the hip, may invite disaster.

Low osteotomy of the femur, with or without excision of the head of the femur, may have a small place in the treatment of the unilateral dislocation. It appears to confer a measure of stability upon the hip, and may alleviate the pain of osteoarthritis, although it seldom abolishes it completely or contributes materially to an increase in physical activity. By abduction of the distal segment of the femur the apparent shortening of the limb is reduced. The advantages of this are not great, because shortening in itself does not appear to add significantly to the patient's disability. Few patients with a dislocated hip use a raised shoe, and it appears likely that the shortening, by producing abduction of the pelvis on walking, itself contributes to hip stability.

In his original article Schanz (1922) described a transverse osteotomy at the level of the ischial tuberosity in which angulation is obtained without displacement. The results of this procedure in his patients were not described, but Gaenslen (1935) reviewed the results of twelve operations in nine patients. He stressed the importance of forward as well as inward angulation in the control of the hip flexion deformity. The additional shortening after this procedure averaged one inch, and the results in five of his nine patients were good.

Bilateral dislocation—When both hips are dislocated the problems of treatment are far greater than in the unilateral case. Many of these patients are gravely disabled, with pain in one or both hips, pain in the lordotic spine and a gross disturbance of gait. It is uncommon, however, for both hips to give rise to severe pain, and the relief of pain in one hip may be of great assistance.

Arthrodesis of one hip is often held to be contra-indicated when the other hip is dislocated. It is doubtful if this view should continue to be held. Although there may be some difficulty in bringing the arthrodesed leg through if the other hip is grossly unstable, the use of a stick should permit a reasonable gait, provided the arthrodesis is not performed in abduction. The provision of one stable, painless hip may be of great advantage before surgery on the other side is considered.

The results of cup arthroplasty in bilateral dislocations are closely related to the relief of pain. When both hips require operation, or may require it in the future, there are obvious advantages in retaining movement in the joint, and a small range of movement in both hips has an importance that it lacks in unilateral procedures. Nevertheless, the chances of success in any form of arthroplasty are not high enough to recommend its performance on both hips.

Subtrochanteric osteotomy of the femur of the Schanz type, supplemented if necessary by excision of the femoral head, is an operation that is applicable to both hips. The loss of active flexion of the hip, which commonly occurs after excision of the head, may make movement more difficult, and, although an osteotomy will normally increase hip stability, the functional result is often disappointing. It must therefore be regarded primarily as a salvaging procedure in the elderly or after an arthroplasty which has failed. Within this limited scope the results are acceptable.

There were only eight patients in this series in whom operations had been performed upon both hips. A measure of relief from pain, and a slight increase in physical activity has been achieved in two of them, and two stated that they have been unchanged by the operations. The other four patients appear to have been made worse. Although it must be admitted that these are hips that were rapidly deteriorating, results of this kind suggest that the methods of treatment which have been reviewed are of little assistance in the patient in whom both hips are painful. The presence of a painless dislocation, however, should not hazard unduly the chances of a successful operation on the other side.

SUMMARY

1. The results of fifty-three operations in forty adults with a persistent congenital dislocation of the hip have been reviewed.
2. Arthrodesis as a primary operation was successful in five of six patients, giving a pain-free hip and good function. After an arthroplasty or an osteotomy that had failed to relieve symptoms it was successful in only one patient.
3. Cup arthroplasty on one hip relieved pain in five of nine patients, giving an increase in functional activity, although the range of hip movement was often disappointing. Bilateral cup arthroplasty, performed in four patients, gave partial relief in three, but did not permit an increase in activity.
4. High osteotomy of the femur was undertaken in eleven patients with a unilateral dislocation; pain was rarely relieved, and a stiff hip resulted in seven.
5. Low osteotomy in nine patients gave some relief from pain with a good range of hip movement.
6. In unilateral dislocation arthrodesis appeared to be the operation of choice, although cup arthroplasty was capable of giving a good functional result.
7. In bilateral dislocation, when only one hip was painful, the results of both these operations were on the whole good. When both hips were painful the operations that had been performed seldom gave clinical improvement.
8. High osteotomy of the femur appeared to have little place in the treatment of the painful dislocated hip. Low osteotomy, either of the Schanz or Batchelor type, appeared to be of value mainly as a salvage procedure when other measures had failed to give relief.

It is a pleasure to record the assistance which has been given to me during these investigations by Mr J. S. Batchelor and Mr H. J. Seddon. I am greatly indebted to Mr E. P. Brockman, Mr R. C. F. Catterall, Mr J. A. Cholmeley, Mr J. Crawford Adams, Mr A. T. Fripp, Mr S. L. Higgs, Mr H. Jackson Burrows, Professor J. I. P. James, Mr W. A. Law, Mr P. H. Newman, Mr K. I. Nissen, Mr H. Osmond-Clarke, Mr R. Y. Paton, Mr T. T. Stamm, Mr D. Trevor and Mr H. L.-C. Wood, who have all permitted me to examine and report upon their patients.

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CONGENITAL DISLOCATION OF THE HIP IN IDENTICAL TWINS

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As early as 1678 Paré stated that lame people beget lame children, and in 1882 Krönlein compiled the family trees of many generations of children with congenital dislocation of the hip. In series of patients with congenital hip dislocation a hereditary factor was noted in 20·2 per cent by Isigkeit (1928), in 22·7 per cent by Scaglietti (1932) and in 6·1 per cent by Francillon (1937). Mercer (1950) stressed the importance of the hereditary influence.

A different emphasis is given by those who believe that the essential cause of the dislocation is intra-uterine pressure from oligohydramnios with unusual transverse lie, breech presentation and prolonged abnormality of position of the femoral head in relation to the pelvis during intra-uterine life. The particular relation of this to anteversion of the upper end of the femur was discussed by Krida (1928), Le Damany (1908), Badgley (1943) and Somerville (1953*b*). Lorenz and Reiner (1905) ascribed an important role in the etiology to hereditary influences, but at the same time tried to develop a mechanical theory.

It was expected that a study of twin children might yield a decisive contribution, and this was in fact possible in the remarkable series reported by Idelberger (1951), who himself examined 138 living identical twins with congenital dislocation of the hip. Before discussing his conclusions we report an example of congenital dislocation of the hip in Italian twin sisters who came north to Switzerland with the influx of Italian workers.

CASE REPORT

Maria and Giacomina B. were born in 1932 in the neighbourhood of Brescia in Northern Italy. They were identical twins as shown by the identical phaenotypus, the genotypical identity of the ABO and Rhesus systems, and the Kell, NN and Duffy blood factors which were present or absent in like quantities. The twins had found difficulty in learning to walk but were first seen by a doctor at the age of three years. They limped but had no pain. Even now at the age of twenty-five years Maria has no pain and cleverly conceals her limp; but Giocomina developed pain in the dislocated hip after an appendix operation and has recently been treated by subtrochanteric abduction osteotomy.

Figures 1 to 4 show the clinical and radiographic appearances. These are mirrored almost exactly in the two girls. Giacomina has congenital dislocation of the right hip with a false joint above the acetabulum, a stress fracture of the right pubic bone and a left-sided convergent strabismus. Maria has a congenital dislocation of the left hip with a false joint, stress fracture of the right pubic bone and right-sided strabismus concomitans convergens.

DISCUSSION

These mirrored defects in twins are well recognised as favouring a *vitium primae formationis*, as demonstrated for example in Speemann's string experiments on salamander eggs, in which the resultant identical twins showed bilateral symmetry in the 50 per cent occurrence of *situs inversus*. Ophthalmologists report that when strabismus occurs in identical twins it affects opposite eyes in 70 per cent. We cannot explain the fact that the fatigue fractures occurred in the right pubic bone in each child. Their occurrence on the same side

does not suggest a direct hereditary influence; but on the other hand if the fractures developed from simple mechanical stress it seems likely that they should both have developed on the side of the normal hip with its greater weight bearing, or both on the side of the dislocated hip with its porotic bones.

Congenital dislocation of the hip in twins has been reported by Hale (1926, one case in identical twins), Hooff (1928, one case in identical twins), Nitsche and Armknecht (1933, one case in identical twins and one in non-identical twins) and Ihlenfeldt (1948, one case in identical twins). Idelberger (1951) reviewed the reports of 22,004 congenital dislocations of the hip and found among them 236 pairs of twin children. He personally examined 138 living identical twins with congenital dislocation of the hip. From his investigations he showed that there was no increased incidence of this congenital disorder in twin children; in fact the incidence tended to be less in twins than in the average population. A similar conclusion was reached by Hass (1951). Clearly such intra-uterine constriction or pressure as may arise in twin pregnancy has no decisive influence in the occurrence of congenital dislocation of the hip as has been asserted by the supporters of mechanical theories of etiology. Furthermore, there was no greater incidence of breech presentation or other abnormal position at birth in Idelberger's twins than is the average with twin births. The frequency of other malformations corresponded in these twins to that recorded in single babies. Of the identical twins with congenitally dislocated hips 42·7 per cent were concordant—that is, both twins had a dislocated hip; whereas the concordance in binovular twins is only 2·8 per cent.*

The proof that mechanical influences of the twin pregnancy do not play a decisive part in the occurrence of dislocation of the hip, and the great concordance in identical twins, show that hereditary factors are of prime importance in congenital dislocation. The hereditary process seems, according to Idelberger, to be dependent on sex, and to be an irregular dominant and of varying penetration. In Idelberger's large series of identical twins there were many cases in which the correspondence extended even to anatomical details of the dysplasia and even to some of the secondary osteoarthritic lesions. However, the fact that congenital dislocation of hip is determined by hereditary factors does not mean that genetic factors alone bring about dislocation. The part played by external factors, such as extension of the hips resulting from upright posture and gait, is quite plausible. It is known that many hips do not dislocate until the child begins to stand up and walk. But these external factors can cause dislocation only if dysplasia of the hip is present. The dysplasia of genetic origin seems to be the prerequisite for the development of typical congenital dislocation of hip. This inherited dysplasia can be present in varying degree: often the dysplasia is so slight that the external causes are not enough to produce dislocation, yet it is sufficiently marked to predispose to osteoarthritic changes at a relatively early age.

The idea that congenital dislocation of the hip develops as an inherited dysplasia of the acetabulum and upper end of the femur, whereby the upright posture cannot be supported, has an influence on our choice of treatment. The inherited dysplasia prejudices every form of treatment, as experience has proved. Reduction of the dislocation alone suffices only in a few cases—namely those in which the dysplasia has reached only moderate proportions or is discovered very early. Reduction alone does not correct the disturbance in the mechanics of the joint which is associated with the dysplasia. The aim of treatment therefore consists in restoring functional conditions as nearly normal as possible in the dysplastic joint and in allowing function of the joint as soon as possible. Early use has a favourable effect on dysplasia, whereas prolonged immobility has an unfavourable influence. Even with treatment that fulfils the requirement of restoring early function (Somerville and Scott 1957) there remains a risk that osteoarthritis will develop years later in consequence of the original dysplasia.

* The concordance of congenital dislocation of the hip in identical twins thus exceeds that in the case of congenital club foot. Idelberger found in 242 twin pairs with congenital club feet a concordance of 22·9 per cent in identical twins and of 2·3 per cent in binovular twins.

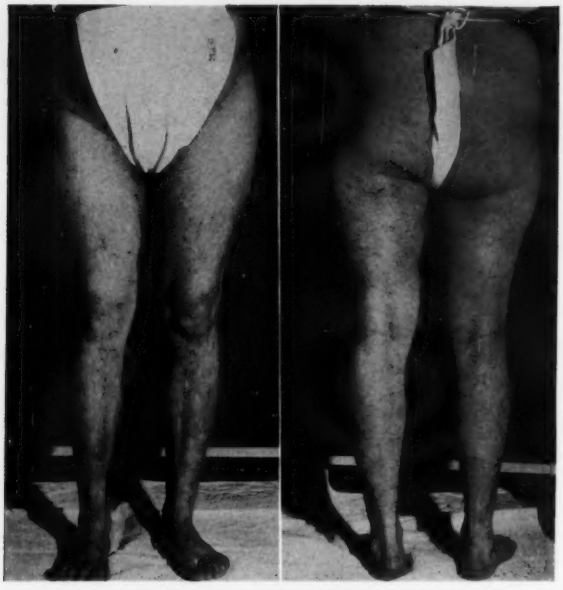

FIG. 1—Giacomina

FIG. 2—Giacomina.

FIG. 3—Maria

FIG. 4—Maria.

SUMMARY

1. Congenital dislocation of the hip in identical twins is reported.
2. The heredity of congenital dislocation of hip is discussed. Studies in twins show that congenital dislocation of hip is probably a hereditary dysplasia of the acetabulum and upper end of the femur, and that external factors play a less important role.

We wish to thank Dr A. Haessig, of the Central Blood Laboratory of the Swiss Red Cross, for the blood examinations.

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MECHANISM OF DERANGEMENTS OF THE MEDIAL SEMILUNAR CARTILAGE AND THEIR MANAGEMENT*

ARTHUR J. HELFET, CAPE TOWN, SOUTH AFRICA

MECHANICS OF THE KNEE JOINT

The rotation element—The key to the function of the knee joint, and to its derangements, is the rotation of the tibia on the femur which occurs on flexion and extension movements. The knee is not a simple hinge joint. The opening and shutting of the front of the joint in the act of flexion and extension involves the tibia in a winding course set by the configuration of the medial condyle of the femur (Fig. 1). As the tibia passes on the femur from the fully flexed to the fully extended position it descends and then slowly ascends the curves of the femoral condyle and rotates outwards. These movements are reversed as the tibia passes back on the femur to the fully flexed position. The movement of the tibial tubercle, which is easily observed, confirms this spiral action. Moreover it shows that rotation occurs throughout

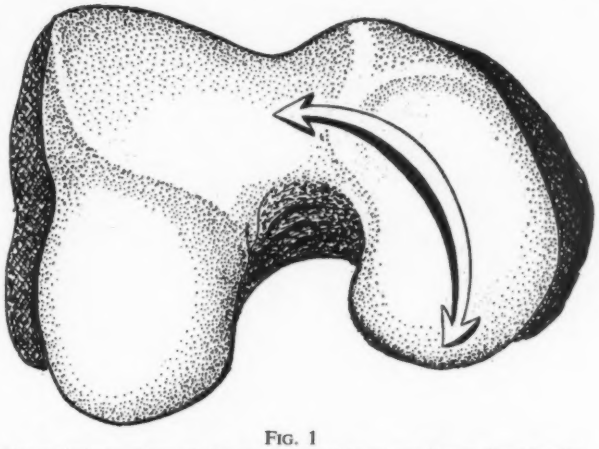

FIG. 1
The articular surface of the medial condyle of the femur showing the helicoid track followed by the tibia in flexion and extension of the knee.

the whole range of movement and not, as was thought previously, only in the last few degrees of flexion and extension. The term *helicoid hinge* would represent this spiral movement precisely. The extent of the rotary movement is roughly equivalent to half the width of the patella. When the knee joint is fully flexed, the tibial tubercle is in line with the medial half of the patella; in the extended knee it is in line with the lateral half of the patella (Figs. 2 and 3).

The anatomy of the muscles and ligaments of the knee facilitates this pattern of movement. The quadriceps group of muscles, running from without inwards, rotate the tibia outwards as the knee straightens. During flexion the popliteus anchors the femur, while the medial hamstrings rotate the tibia inwards. It should be noted that extension and lateral rotation of the tibia are synchronous, as are flexion and medial rotation, both being controlled by the thigh muscles. It is my belief that forcible prevention of this *synchronous* movement is most often responsible for internal derangement of the knee.

* The substance of this paper was presented in a Hunterian Lecture delivered at the Royal College of Surgeons of England on June 17, 1958.

Only when the thigh muscles are relaxed is it possible to rotate the tibia on the femur freely in both directions. Even in relaxation it is not possible to achieve full extension or full flexion without full lateral or medial rotation as the case may be. As the tibia moves

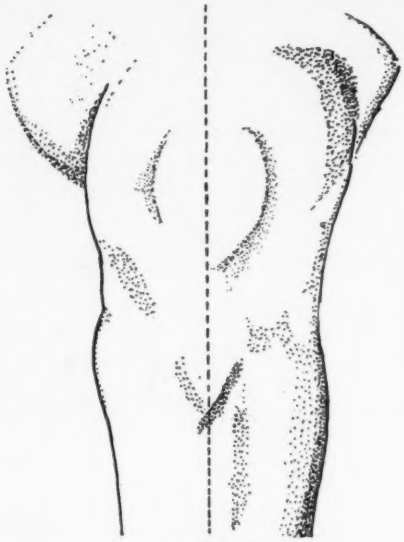

FIG. 2

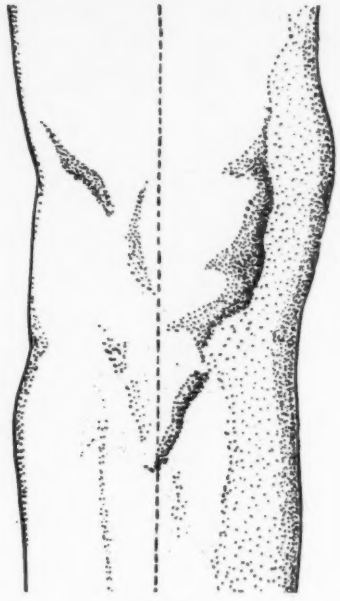

FIG. 3

Figure 2—With the knee flexed to a right angle the tibial tubercle points to the midline of the patella.
Figure 3—In the fully extended knee the line of the tibial tubercle is near the lateral border of the patella

from full extension to flexion its full range of free rotation increases. It should be emphasised, however, that when the quadriceps and hamstrings are active, only synchronous movement in each direction is normally possible: when the knee straightens the tibia must rotate laterally and as it flexes the tibia must rotate medially.

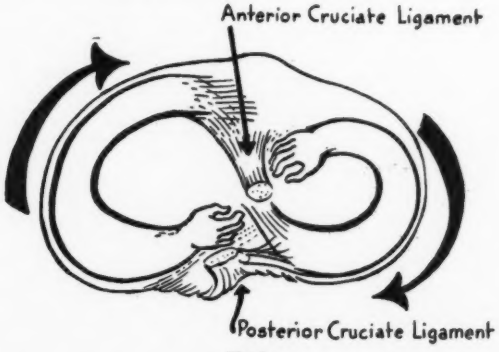

FIG4.
Diagrammatic representation of the guiding action of the cruciate ligaments and semilunar cartilages in the rotator mechanism of the knee joint.

In a previous paper (Helfet 1948) I drew attention to the fact that the cruciate ligaments act not as stays to prevent antero-posterior displacement of the femur on the tibia, but as guide ropes to keep the tibia on its winding path when the knee extends and flexes. Further

consideration suggests that the semilunar cartilages join the cruciate ligaments in this function in the manner suggested diagrammatically in Figure 4, where the semilunar cartilages represent an extension of the cruciate ligaments in this function of guiding the rotation of the tibia on the femur. It is probable that both the cruciate ligaments and the semilunar cartilages are of similar origin, for the cartilages are differentiated from the the same embryological layer in continuity with the cruciate ligaments and are not truly cartilaginous. It seems likely that they function as an accessory part of the rotator mechanism (Kaplan 1955).

The continuity of the ligamentous and cartilaginous structures, in what Sir Harry Platt aptly termed "figures-of-eight" anatomy, was accurately described by Galeazzi in 1927. Three of his illustrations, reproduced here, emphasise this characteristic. Figure 5 shows the strong fibrous band, sometimes a centimetre wide, connecting the posterior horn of the lateral cartilage to the femoral attachment of the anterior cruciate liagment. Figure 6 shows the fibrous bands which connect the anterior cruciate ligament with the anterior horn of the medial and with the anterior horn of the lateral cartilage. Figure 7 shows Barkow's ligament connecting the posterior horn of the lateral cartilage and the anterior horn of the medial cartilage.

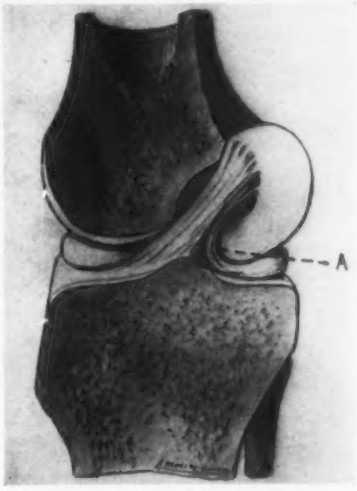

FIG. 5

Strong fibrous band, sometimes a centimetre wide, connecting the posterior horn of the lateral cartilage to the femoral attachment of the anterior cruciate ligament. (From Galeazzi 1927, by permission of the Editor of the *Journal of Bone and Joint Surgery*.)

Galeazzi also referred to the transverse ligament of the knee (Winslow), which joins the anterior horns of the two cartilages, and emphasised particularly the firm attachments between the anterior cruciate ligament and medial cartilage. All this is important to my thesis.

Watson-Jones (1955) drew attention to the part played by the semilunar cartilages in the rotator mechanism when he described what might be called the *retreating cartilage*. "Place one finger over the joint line of the knee in front of the medial ligament where the

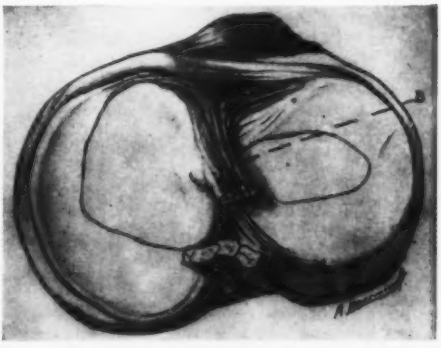

FIG. 6

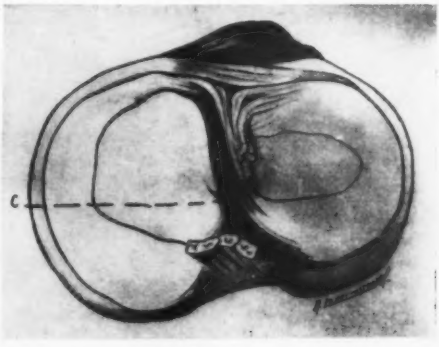

FIG. 7

Figure 6—Fibrous bands which connect the anterior cruciate ligament with the anterior horn of the medial, and B, with the anterior horn of the lateral cartilage. (From Galeazzi 1927, by permission of the Editor of the *Journal of Bone and Joint Surgery*.) Figure 7—Barkow's ligament connecting posterior horn of lateral cartilage to anterior horn of medial cartilage. (From Galeazzi 1927, by permission of the Editor of the *Journal of Bone and Joint Surgery*.)

curved margin of the medial femoral condyle approaches the tibial tuberosity. Now rotate the foot and leg laterally. It is easy to feel the medial semilunar cartilage disappearing from the surface, leaving a sulcus between the bones." This sign is present when the knee is flexed and the muscles relaxed and is presumably an expression of the independence of the figure-of-eight mechanism, of which the cartilage is only a part, when rotation is unaccompanied by synchronous extension of the knee. Normal lateral rotation of the tibia when the knee is straightened does not produce this sign: the cartilage maintains its relationship to the margin of the tibia.

On the other hand, when, as will be shown, rupture of the cartilage blocks lateral rotation of the tibia, absence of the " retreating " cartilage sign in the flexed knee may be used diagnostically.

The patella—The patella is a pulley, and its excursion is controlled by the direction of action of the quadriceps group of muscles and the position of the tibial tubercle which carries the patellar ligament.

FIG. 8

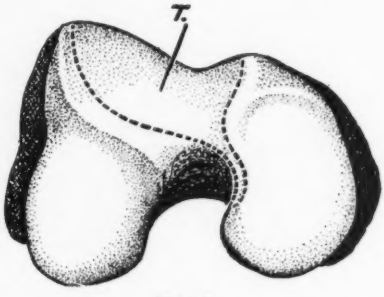

FIG. 9

Figure 8—Patella showing smaller medial slope with vertical division into two planes A and B. Figure 9—Lower end of right femur showing trochlear surface (T), for patella, extending along inner condyle as an area with which patella articulates in flexion. (From Frazer's *Anatomy of the Human Skeleton*, by permission of Messrs J. & A. Churchill.)

The articular surface of the patella is divided into a large lateral and a smaller medial surface. These surfaces are separated by a vertical rounded ridge (Fig. 8). In full extension its shape fits comfortably and evenly into the trochlear surface of the femur. The ridge then lies in the hollow or trough of the trochlear surface. When the knee is bent the patella is carried downwards and backwards on the under aspect of the femur where the trochlear surface is prolonged on to the inner condyle (Fig. 9). In flexion the patella tilts away from the lateral condyle, so that only the inner part of its articular surface rests against the medial condyle (Frazer 1958).

So long as the tibial tubercle rotates smoothly, the patella travels its short course smoothly and under even tension. However, any derangement of the joint which prevents lateral rotation of the tibia during extension of the knee would affect normal tension, because contraction of the quadriceps would force the inner border of the patella against the medial condyle of the femur. This explains the patellar symptoms and signs produced by certain cartilage injuries—such as retropatellar pain on climbing and descending stairs, tenderness of the medial border of the patella, and the pattern of cartilage erosion which develops on the medial surface only of the patella and femur. This pattern differs from that produced by retropatellar arthritis complicating recurring dislocation, in which case the lateral surface of the patellar cartilage undergoes fibrillation (Langston 1958).

MECHANISM OF INTERNAL DERANGEMENTS OF THE KNEE

Types of violence—With weight bearing, the knee joint straightens and the tibia rotates laterally. It rotates medially when the knee flexes. If this synchrony is forcibly prevented—as by the weight of the falling body—the rotator mechanism of the knee is injured. Certain cartilage tears are caused by nothing more than this disruption of the rotator mechanism of the knee.

Figure 10 shows a common manner of injury of the footballer's knee. He catches his toe, trips and falls while the foot and tibia are outwardly rotated: flexion occurs without medial rotation.

FIG. 10

FIG. 11

Figure 10—The footballer catches his toe, trips and falls. The foot and tibia are outwardly rotated while the knee flexes. Figure 11—An uncontrolled twist while weight is taken on the fully flexed knee may tear the medial cartilage.

Figure 11 shows the position in which miners and those who do housework frequently injure the medial cartilage. An uncontrolled twist—rotation without synchronous extension—is followed by a searing pain, the signal of a tear in the cartilage. One patient, a carpenter, was working in front of a chest of drawers in this attitude. A drawer had jammed. He wrenched vigorously to open it. The drawer gave suddenly. He twisted on his right knee and immediately he felt a searing pain over the medial cartilage. To relieve the agony he threw himself on to his left knee, with identical consequences to that joint. At operation bucket-handle tears of both medial cartilages were found.

In another instance a woman knelt on her kitchen sink to open a cupboard above it. The door opened suddenly and she twisted on the flexed knee. A stab of pain signalled detachment of the anterior end of her medial cartilage.

MEDIAL CARTILAGE LESIONS

It seems that if synchronous rotation is prevented, flexion is achieved either by pulling the medial cartilage away from its anterior attachments (Figs. 14 and 16) or by splitting the cartilage longitudinally to allow the free border to bowstring across the joint (Figs. 13 and 15).

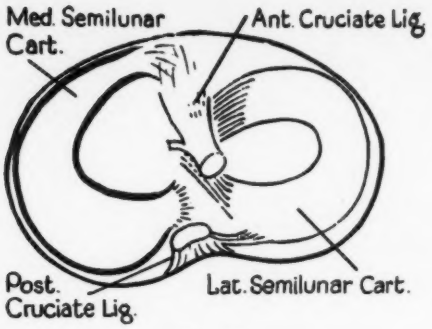

FIG. 12
The relationship of the semilunar cartilages and cruciate ligaments.

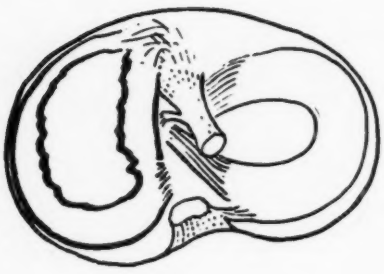

FIG. 13

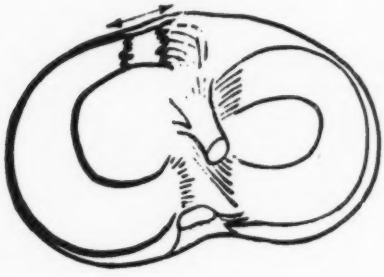

FIG. 14

Figure 13—The bucket-handle or bowstring tear of the medial semilunar cartilage. The separation is roughly equivalent to the distance the tibia normally rotates. Figure 14—The retracted cartilage: rupture of the anterior horn of the medial cartilage from its ligamentous attachments.

FIG. 15

FIG. 16

Figure 15—Diagrammatic presentation of the bowstring cartilage as seen from the front. Figure 16—Diagrammatic presentation of the retracted cartilage as seen from the front.

As the complete range of rotation is at most half the width of the patella the displacement need not be extensive, and it is always within this measurement. In either case the figure-of-eight rotator mechanism is interrupted. As the anterior end of the cartilage is detached the whole cartilage retracts and a gap forms between the attachment of the cruciate ligament and the torn edge. At operation the gap may be recognised and, in a young patient, the free edge of the cartilage will present a ruffle which raises it from the surface of the tibia. The front half of the cartilage is slack and looks too long: by the inexperienced it may be considered a " lax cartilage." In an older patient, with fibrotic and less resilient cartilages, retraction causes a thickening of the anterior half of the cartilage, which is yellowish, hard and triangular in section and a heaped-up mass is formed in the anterior compartment of the joint. The lump so formed produces a pattern of erosion over the corresponding area of articular cartilage on the antero-medial part of the weight-bearing surface of the medial femoral condyle (Fig. 17). As this type of cartilage tear presents its own clinical features and sequelae, I submit that it

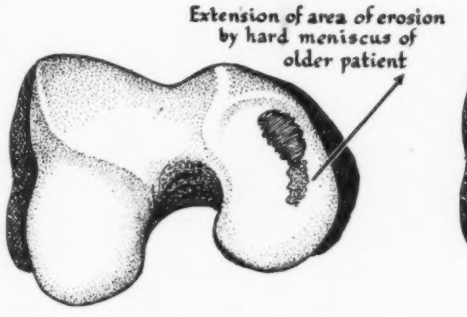

FIG. 17

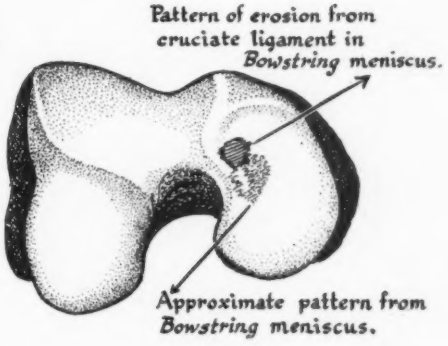

FIG. 18

Figure 17—Pattern of erosion caused by heaped-up retracted cartilage. Figure 18—Pattern of erosion caused by bowstring cartilage.

should be known as the " retracted " cartilage to distinguish it from the " bucket-handle " cartilage, which itself should more aptly be named the " bowstring " cartilage. In the latter type of injury the whole, or part, of the cartilage is bowstrung across the joint, and the symptoms are more severe than in the case of the retracted cartilage. But if at the first attack or subsequently the bowstring snaps and coils up at the fixed end in the anterior compartment, the clinical picture resembles that of the retracted variety. The " bowstring " injury produces a pattern of erosion on the articular cartilage covering the intercondylar border of the condyle of the femur (Fig. 18) (Helfet 1948).

In November 16, 1883, Thomas Annandale (1885) performed the first recorded operation for displaced semilunar cartilage. He found " that the internal semilunar cartilage was completely separated from its anterior attachment to the tibia and was displaced backwards about half an inch." He did not excise the cartilage but cured his patient by drawing the cartilage forward and stitching it to its former attachment. Ten weeks later the man was back at his work with a normally functioning knee. This historical note not only records the " retracted " cartilage for the first time, but may well indicate an approach to treatment.

Less frequently the posterior end of the cartilage is torn or detached. Only once have I found the whole back end of the cartilage wrenched from its attachments and the entire cartilage coiled in the anterior compartment. This injury was suffered by an amateur in a wrestling match, but we were unable to reconstruct the exact mechanism.

A review of a recent personal series of 232 operations for cartilage injuries reveals that retracted and bowstring cartilages are the most frequent consequences of injury (80·6 per cent) (Table I). In the whole series the bowstring tears exceeded the retracted cartilages by 11 per cent, but with increasing age the relative incidence of anterior tears increased (Table II). This must mean that as the cartilage becomes less resilient and more fibrotic, it is more liable to tear from its ligamentous moorings than to split in its substance.

TABLE I

TYPES OF CARTILAGE INJURY (232 CASES)

	Number	Per cent
Retracted cartilage	81	34·9
" Bowstring " or bucket-handle cartilage	106	45·7
Posterior tears	26	11·2
Other tears	19	8·2

TABLE II

TYPE OF INJURY RELATED TO AGE OF PATIENT

Age (*years*) . .	10–19	20–44	45 and over
Retracted cartilage .	14 (35%)	53 (43%)	14 (58%)
" Bowstring " cartilage	26 (65%)	70 (57%)	10 (42%)

CLINICAL FEATURES

Restriction of movement—Tears and displacements of the medial semilunar cartilage affect the smooth action of the rotator mechanism of the knee, and the presence of injury is signified in every instance by inability to rotate the tibia laterally to its full extent and, therefore, to extend the knee completely.

The bowstring cartilage blocks these movements. To call it "locking" of the joint is inaccurate because only extension and lateral rotation are prevented. Flexion and medial rotation are unaffected and give comfort to the injured joint. The retracted cartilage has the same effect but is not so painful. At the start I reasoned that, since the anterior cruciate ligament exerted its guiding action on the tibia in part through the medial cartilage, anterior detachment of the cartilage would weaken this function and leave the tibia unable to complete its normal excursion. But this cannot be so, for after excision of the torn cartilage the quadriceps regains full control of the range of rotation and incidentally of extension of the tibia. The cartilage is an accessory factor in the rotator mechanism. The abnormal cartilage disturbs function, but when it is excised the knee can compensate for its absence.

It appears that any increase in volume of the contents of the antero-medial compartment of the knee prevents full lateral rotation of the tibia. This can be demonstrated experimentally at operation. Through the usual medial incision with the knee bent over the end of the table, the lateral rotation of the tibia during extension shows very well. If one puts a sterile rubber catheter across the medial joint space, the tibia cannot rotate fully. The reaction to the anterior tear is therefore a blocking of movement by the " heaping-up " of the retracted cartilage.

This blocking of movement of rotation and therefore of extension gives us the following four clinical signs which are pathognomonic of displacement or swelling of the medial cartilage. 1) Forced passive extension produces finger-point pain over the site of injury in the antero-medial compartment of the joint. The patient can locate the pain exactly. 2) Any attempt to force the final degree of lateral rotation will cause pain localised to the same spot. Flexion and medial rotation of the knee are not affected and, indeed, give the patient comfort. This statement needs a word of qualification, because if the effusion in the knee is tense, flexion is limited and painful because of the distension of the capsule as a whole; and if the split in the bowstring cartilage extends to the posterior compartment the final degrees

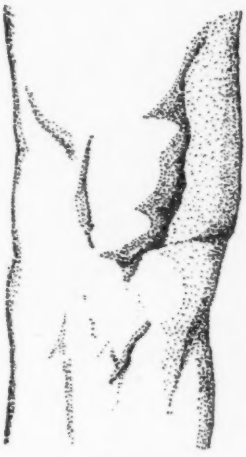

FIG. 19

FIG. 20

Figure 19—Diagram of the " blocked " knee showing: 1) that line of tibial tubercle remains near the midline of the patella; and 2) that the medial femoral condyle protrudes over the margin of the tibia. Figure 20—The protrusion of the medial femoral condyle and the blocked rotation of the tibial tubercle are obvious in this knee, with a retracted medial cartilage.

of flexion and medial rotation may also be obstructed. 3) Compared with the normal knee the outward excursion of the tibial tubercle is limited. When the normal knee is straightened the tibial tubercle reaches the line of the lateral border of the patella. The tibial tubercle of the injured knee reaches approximately to the central axis of the patella (Figs. 19 and 20). 4) The final screw-home of the knee in completing extension aligns the borders of the medial femoral condyle and the adjacent tibia exactly. When the screw-home is prevented by an injured cartilage, the femoral condyle is left protruding over the margin of the tibia. Unless the knee is very swollen this is obvious to the eye (Fig. 20). In any case, it can be detected by palpation. If the examining finger follows the subcutaneous surface of the tibia upwards it will, when it reaches the knee, be obstructed by the protruding medial condyle of the femur, a feature which may be confirmed by comparison with the normal knee. The protrusion is most obvious in the knee in which arthritic changes have become established.

At operation for a torn medial cartilage these signs may be confirmed. After opening the joint through a medial incision, straighten the knee. The medial femoral condyle overlaps the tibial margin. Remove the cartilage and straighten the knee again. Complete extension is obtained and the femur and tibia are in perfect rotational alignment.

Tenderness—After the injury the whole cartilage may be sensitive, but after a while the retracted cartilage will be tender in the anterior compartment, and the cartilage with a posterior tear in the posterior compartment. The complete bowstring cartilage may be tender at both ends. In the case of an untreated tear tenderness subsequently develops in two other areas. The retracted cartilage, by virtue of its local increase in bulk in the anterior compartment, gradually erodes an area of weight-bearing articular cartilage on the medial femoral condyle (Fig. 17). The spot is adjacent to the femoral condyle protrusion (previous paragraph) and is most easily located when the knee is flexed. The other site of tenderness is the medial border of the patella and the adjacent medial slope of the trochlear surface of the femur; it is the consequence of injury to articular cartilage by undue tension between these surfaces of the patella and femur.

PAIN AND ITS MECHANISM

It is interesting to establish a pathological basis for the various sites and types of pain that follow injury to the medial cartilage. The bowstring tear causes immediate and severe pain. The patient cannot continue to take weight on the leg. During the next two or three weeks the symptoms improve, though forcing the knee straight or turning suddenly remain painful movements. With time the cruciate ligaments stretch, the patient develops slight antero-posterior laxity, and the knee becomes more comfortable. Each recurrence of the derangement produces less severe symptoms until finally the articular cartilage is eroded and the symptoms of " arthritis " develop—namely, aching and swelling after effort, subsiding with rest, and pain and aching referable mainly to the medial compartment of the knee. Later, when the patella becomes involved, the disconcerting symptom is increased pain on descending and ascending stairs, from increased pressure between the medial border of the patella and the medial trochlear surface of the femur.

The injury that causes the " retracted " cartilage gives less pain. The patient may experience a sharp momentary pain, which is relieved when the twist is corrected. The joint swells, and there are recurrent stabs of pain on sudden movements. Later, when the articular cartilage is eroded, the more distressing symptoms of arthritis become manifest. These are pain in the medial compartment of the knee on walking, and aching after effort and later at night. The patient may feel that he is " walking with a stone in the knee." The ache is localised to the same area. The patellar symptoms, when they develop, are like those produced by the bowstring cartilage.

FIG. 21

ARTICULAR EROSIONS

The essence of normal function of the knee is synchrony of movement and weight bearing without undue tension at any time. In a previous article (Helfet 1948) the suggestion that the cruciate ligaments acted as guide ropes, and not as straps to check movement, carried this implication. The tension in the cruciate ligaments in all normal—and therefore synchronous—movements remains even. If the ligaments acted as checks

FIG. 21

The arrow indicates the point at which the anterior cruciate ligament hooks over the edge of the medial condyle of the femur if rotation is prevented during extension. Recurrent or longstanding " locking " of the knee causes erosion of the articular cartilage there and inflammation of the corresponding part of the cruciate ligament. Note the loss of rotational alignment between the femur and tibia. (Reproduced from the *Lancet* by permission of the Editor.)

to antero-posterior movement then at times the tension would increase. In normal movements this does not happen. The experiments on cadaveric knees (Galeazzi 1927) to demonstrate increase in tension are basically unsound because in each case movement is tested in only one direction, and any movement without its synchronous counterpart is an abnormal movement.

Conversely, when rotation is prevented during extension, the cruciate ligament is tensed. It impinges on the lateral edge of the medial femoral condyle and in time erodes the surface of the articular cartilage in this area. In turn the cruciate ligament suffers from the continuous or recurrent tension and is slowly stretched, with consequent laxity of the joint; at operation it may show a raw area of granulation on its otherwise shining surface (Fig. 21).

The effect of the retracted cartilage differs with age. The youthful soft cartilage is heaped up or ruffled. The antero-medial part of the weight-bearing surface of the medial femoral condyle comes into contact with the thickened anterior part of the retracted cartilage when the

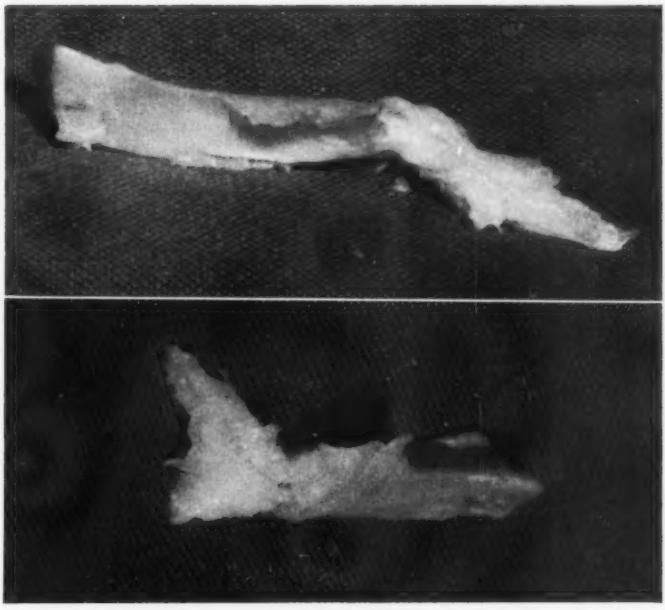

FIG. 22

Two views showing the thickened triangular shape of the front part of the retracted cartilage and the splayed squashed edge at the site of fracture.

knee is extended, and is slowly worn away (Fig. 17). But, because of the protrusion of the femoral condyle, the area of erosion never reaches the edge. Consequently, after the torn cartilage is removed and full extension and rotational alignment of femur and tibia are regained, normal cartilage is brought back to the weight-bearing area: this is one of the reasons why it is worth while removing the retracted cartilage, however long its history and whatever the age of the patient.

At operation upon older patients the cartilage may be seen to be yellowish and hard. It forms a shorter triangle on section because the free edge has contracted. The narrow hard cartilage tends to erode a more linear groove on the femoral condyle and the area of erosion seems to extend farther backwards (Fig. 17). At this age, too, transverse tears in the middle third of the cartilage are more common (Fig. 22). The torn back end of the front part has a splayed, squashed and scalloped edge. It seems that the heaping up or thickening caused by

the anterior retraction is all taken up in this front portion and that eventually the weight-bearing surfaces nip it off at this junction between thickened and normal portions of the cartilage.

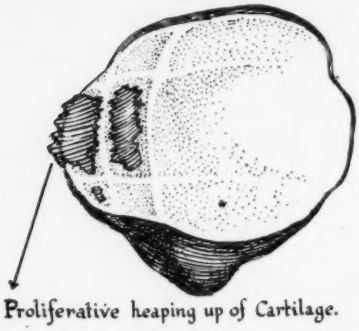

FIG. 23

FIG. 23
Maximum erosion over areas A and B of Figure 8 with proliferative changes along the medial border of the patella.

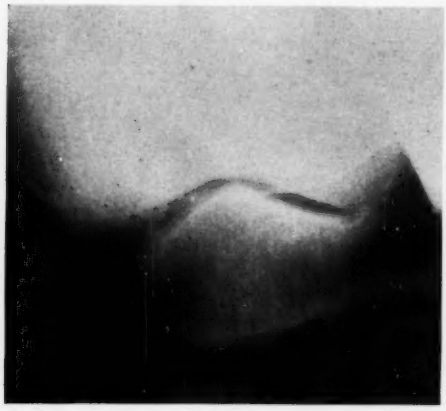

FIG. 24

FIG. 25

Figure 24—Axial view of right patella showing erosion of articular cartilage in area B and of corresponding area of trochlear surface of femur. Figure 25—Degenerative changes on medial articular surface of patella.

FIG. 26
Pattern of erosion of medial trochlear surface of femur from patella.

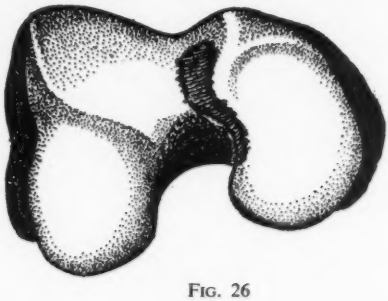

FIG. 26

The third pattern of erosion concerns the medial border of the patella and the surface of the femur with which it is in contact. Attention has been drawn to the effect produced by inadequate excursion of the tibial tubercle on the relationships of the patella and femur.

Normally, in full extension, the line of action of the quadriceps on the patellar ligament settles the patella comfortably on the trochlear surface of the femur. When the tibial tubercle halts short of this line the patella will deviate medially as the knee extends, and particularly when the quadriceps contracts against increased resistance as in climbing and descending stairs. It is tensed against the medial slope of the trochlear surface of the femur and the tension is greatest over the area A and B in Figure 8 of the patella and area T of Figure 9 of the femur. These are the sites of articular cartilage erosion. (See also Figures 23 to 26.)

During flexion from complete extension the increased medial pull on the whole mechanism produces increased pressure by the patella as it slips downwards and backwards on the extension of the trochlear surface on the medial condyle of the femur, and gradually the complete pattern of traumatic arthritis of the knee is etched.

FIG. 27

FIG. 28

Case 1. Figure 27—The preoperative radiograph shows that in the limited extension possible the patella is squeezed against the undersurface of the medial femoral condyle and there is erosion of joint surface between the patella and trochlear surface of the femur. Figure 28—Comparable radiograph of the knee after removal of the medial cartilage. The knee is straighter and the patella tips back into the trochlear space.

Normally, in the flexed position the patella tilts on to its medial articular surface. This tilt is accentuated in the blocked knee and will be present even in the position of fullest extension.

CASE REPORTS

Case 1—Figures 27 and 28 show lateral radiographs of the knee of a man of seventy-two with a longstanding retracted medial cartilage. The radiograph taken before operation shows that in the limited extension possible the patella is squeezed against the undersurface of the medial femoral condyle and there is erosion of the joint surface between the patella and the trochlear surface of the femur. In the radiograph taken after removal of the medial cartilage the knee is seen to be straighter and the patella tips back into the trochlear space.

This patient had no trouble with the knee until January 1957, when he twisted it. Since the accident he had been unable to straighten the knee completely and walking had been painful. These

FIG. 29
Case 1—Showing so-called arthritis of the knee.

symptoms gradually worsened, and he suffered a gnawing ache in bed at night. When walking he felt as if there was a stone or lump in the medial compartment of the knee: this was relieved by bending the knee, and he tended to limp with the knee in a more and more flexed position.

On examination, extension was limited by fully 20 degrees. The anterior horn of the medial cartilage and the articular surface of the femoral condyle were acutely tender. The signs of femoral protrusion and lack of rotation of the tibia were positive (Fig. 29). Radiographs showed erosion of the femoral articular surface and of the patella, with osteophyte formation.

At operation the medial compartment of the knee was opened. When the knee was extended the medial condyle of the femur protruded and lateral rotation of tibia was restricted. After removal of the medial cartilage rotation of the tibia was immediately restored and the knee could be extended fully. There were areas of erosion on the medial femoral condyle and on the medial facet of the patella. The findings are illustrated in Figures 30 to 36.

Progress after operation was rapid. The knee could be extended almost completely. The gnawing ache disappeared, and three months after the operation he was able to walk and climb stairs without pain.

Comment—I have deliberately presented the history of a patient who had extensive arthritis with erosion due to a torn medial cartilage, for it shows that even at a late stage the simple excision of a cartilage is desirable. In the earlier stage not only are symptoms relieved and

FIG. 30

FIG. 31

Case 1. Fig. 30—Shows knee extended, with protrusion of medial condyle of femur and limited lateral rotation of tibial tubercle. Figure 31—After removal of medial cartilage. Immediately the tibia rotates the knee extends fully.

FIG. 32

FIG. 33

Case 1. Figure 32—Knee extended. Protrusion of femoral condyle over margin of tibia. Lower hook grips retracted cartilage. Note presence and heaping up of articular cartilage on presenting surface of femur. Area of erosion is in relation to the cartilage. Figure 33—Knee extended. After removal of cartilage. Realignment of margins of femoral condyle and tibia.

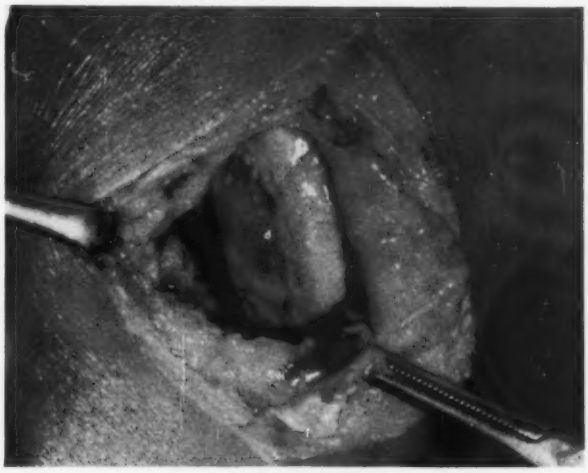

FIG. 34

Case 1—Compare with Figure 17.

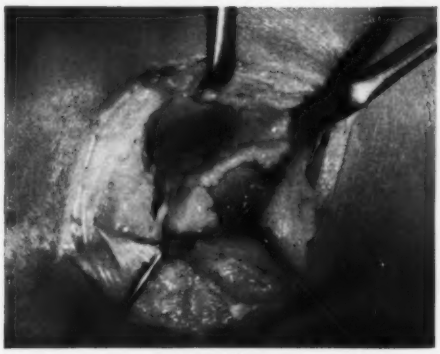

FIG. 35

FIG. 36

Case 1. Figure 35—Knee extended. Patella retracted. Area of erosion on medial slope of trochlear surface. Figure 36—Showing the smooth unaffected lateral slope of the trochlear surface of the femur.

FIG. 37

FIG. 38

Case 2. Figure 37—Shows the linear erosion on the anterior part of the articular surface of the femoral condyle. Figure 38—Shows the erosion on the femoral condyle, linear in the anterior part and broadening out farther back.

function restored, but further degeneration is prevented. After removal of the cartilage the patient is taught to extend the knee fully. Normal articular cartilage is brought into the weight-bearing area and, once more, the contracting quadriceps allows the patella to travel in the correspondingly proportioned groove of the trochlear surface of the femur. There is no tension and no pain.

FIG. 39

Case 2—Shows the erosion of the medial slope of the trochlear surface of the femur.

Post-operative care should be planned to teach the patient once more to extend the knee completely. In older patients, especially, this is the main purpose of quadriceps retraining. Unless the patella shows gross degeneration it need not be excised, but the osteophytic protrusions on the medial border should be removed. Older patients are happier with than without the patella.

Case 2—Figures 37 and 38 illustrate the case of a man aged sixty-six. In spite of a gunshot wound of the femur during the first world war, he had enjoyed normal function and played much golf. Six months before consulting me he had fallen on the left knee. The knee was swollen and painful for three weeks. Thereafter he could again play golf but felt uncomfortable after a round, and in the last two months his knee had become progressively worse. He felt pain when he swung against the knee, and towards the end of the game his knee would ache and the leg feel lame. At first the symptoms settled down with rest but finally the pain became constant.

On examination, the four signs that I have described were all present. The knee was tender over the articular surface of the femoral condyle and chiefly on the medial side of the trochlear surface and the corresponding border of the patella. Figure 37 shows a linear erosion on the anterior part of the articular surface of the femoral condyle; the erosion broadened out farther back (Fig. 38). Figure 39 shows the erosion of the medial slope of the trochlear surface of the femur. The erosion on the patella corresponded exactly. The lateral slopes of the articular cartilage of the femur and the patella were unmarked.

After the operation the knee straightened out completely, his convalescence was normal and full function was recovered.

Case 3—Figure 40 shows the findings at operation in a woman aged fifty-one. She did not recall any injury, but complained of intermittent pain and swelling in the right knee for three months. On examination rotation of the tibia was restricted and the femoral condyle protruded. There was tenderness over the anterior end of the medial cartilage, and along the medial border of the patella.

FIG. 40

Case 3—Shows the detached anterior end of the cartilage and the early erosion of the articular cartilage on the opposing femoral condyle.

FIG. 41

Case 3—Retracted cartilage from a younger patient than that shown in Figure 22, but showing the early contraction of the front of the cartilage and the scalloped squashed edge of the fracture.

Forced passive extension caused localised pain over the anterior end of the cartilage, and forced active extension caused pain behind the patella.

Conservative treatment did not help her, and six weeks later the cartilage was removed. The cartilage was detached in front, the anterior two-thirds were thickened and there was an almost complete transverse fracture at the junction of the anterior two-thirds and posterior third. The fractured edge showed the typical scalloped squashed appearance (Fig. 41).

Six weeks later, when she had recovered good function of the quadriceps, she had a full range of comfortable movement.

THE LATERAL SEMILUNAR CARTILAGE

So far I have considered only the torn medial cartilage. Most anterior tears of the lateral cartilage present the same physical signs of limited outward rotation of the tibia, but with the pain and tenderness referred to the lateral compartment. Tears of the lateral cartilage are less frequent—twenty-nine to 203 in a series of 232 cartilage injuries—and have a greater inclination to cause " giving way " of the knee. In some instances tears of the lateral cartilage and of the posterior end of the medial cartilage are characterised not by limitation of extension and lateral rotation, but by limitation of flexion and medial rotation of the tibia, pain if these movements are forced, and tenderness over the posterior compartments of the knee. To determine the exact relationships of symptoms to site of injury requires further investigation, as do the patterns of erosion on the lateral condyle of the femur. I propose to present this aspect of the subject for publication later.

SUMMARY

1. The semilunar cartilages are part of the rotator mechanism of the knee joint.
2. Movement of the weight-bearing knee comprises synchronous lateral rotation of the tibia with extension and medial rotation of the tibia with flexion.
3. When this synchrony is disturbed, injuries to the semilunar cartilages result.
4. Damage to the anterior two-thirds of the medial cartilage blocks lateral rotation of the tibia, with consequent physical signs that are pathognomonic of the retracted and the bowstring cartilage, which are the most common types of injury.
5. Each type of cartilage injury produces its own pattern of erosion of articular cartilage and its own sequence of symptoms as so-called arthritis develops.
6. The sequence of symptoms may be halted and often reversed by removal of the torn cartilage. Operation is warranted in most cases however long the history and whatever the age of the patient.
7. The development of medial retropatellar arthritis is explained. The symptoms are often relieved by removal of the medial semilunar cartilage and adequate post-operative rehabilitation.

I am indebted to Mr Bruce Franck of Cape Town for the drawings and to Mr B. Todt of Groote Schuur Hospital for the photographs.

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THE ANKLE JOINT IN RELATION TO ARTHRODESIS OF THE FOOT IN POLIOMYELITIS

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From the Princess Elizabeth Orthopaedic Hospital, Exeter

Seventy-five years have passed since subtalar arthrodesis was first performed, by Albert of Vienna (1882), to counteract lateral instability in the paralytic club foot, but to Davis (1892) is due the main credit for developing the operation as an established procedure. Soon afterwards Whitman (1901) devised " astragalectomy " [excision of the talus] for calcaneus deformities, an operation which aimed to correct the deformity and to improve the balance of the foot by displacing it backwards upon the bones of the leg. These two principles of subtalar fusion and posterior displacement were incorporated in the operation of triple arthrodesis, which was developed by Ryerson (1923) and Hoke (1921) in America and by Dunn (1922) in England, and further modified by Campbell (1923) and Lambrinudi (1927) to control downward movement in the antero-posterior plane. In one or other of its forms, the triple arthrodesis has remained the standard operation for stabilising the foot in poliomyelitis.

The main purpose of this paper is to consider the late results of these operations in relation to their effect upon the ankle joint and to determine the extent of 1) lateral instability, 2) restriction of antero-posterior movement, and 3) clinical or radiographic evidence of osteoarthritis. These are the late complications which might be expected. A second purpose is to study the results of fusing the ankle as well as the tarsus (pantalar arthrodesis) in cases of flail foot (Steindler 1923). Complete paralysis of the muscles controlling the foot is usually associated with severe weakness throughout the lower limb: surgical reconstruction of the flail foot must therefore be related to the limb as a whole and to extension of the knee in particular.

MODE OF INVESTIGATION

The investigation was related to a series of patients who, more than ten years ago, had undergone arthrodesis of the foot for poliomyelitis at the Princess Elizabeth Orthopaedic Hospital, Exeter, or at the Mount Gold Hospital, Plymouth. As many of the patients as were accessible were re-examined. Information concerning patients who were abroad or in distant parts of the country was obtained from relatives or by correspondence. These cases have not been included in the review, but they raised the proportion of operations traced from 58 per cent to 74 per cent, a figure which is statistically acceptable. The details are given in Table I.

TABLE I

CLINICAL MATERIAL

Feet operated upon	Feet examined	Traced but feet not examined	Untraced
103	60	16	27

Of the sixty feet seen, thirty-three were examined in out-patient clinics and twenty-seven by domiciliary visits. Radiographs were taken if lateral instability or stiffness of the ankle was found.

Age at operation—Forty-six patients were aged between ten and sixteen years at the time of operation; in the whole series the youngest was aged eight years and the oldest fifty-three years.
Length of follow-up—Figure 1 shows the length of follow-up—that is, the number of years since the date of operation.

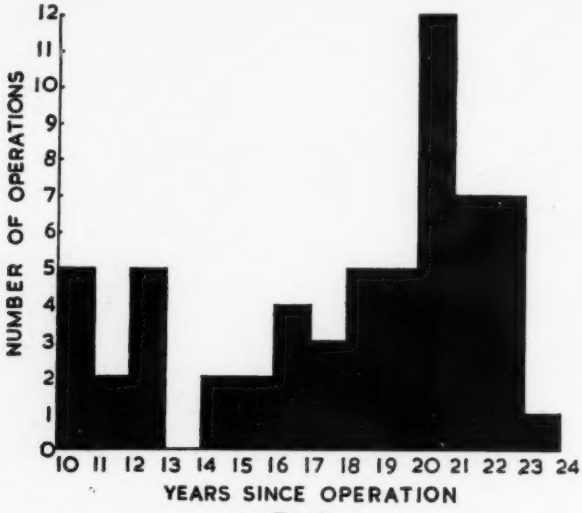

FIG. 1
Length of follow-up.

Nature of operation—The types of operation reviewed are listed in Table II. Most of the triple arthrodeses were of the Dunn type. Twenty-seven operations were associated with tendon transfers. On every occasion the subtalar joint was widely opened and the foot fully inverted. The pantalar operations were performed in one stage.

TABLE II
DETAILS OF OPERATIONS

Procedure	Number
Subtalar arthrodesis	4
Triple arthrodesis	42
Campbell's bone-block	2
Lambrinudi's arthrodesis	4
Pantalar arthrodesis	8
Total	60

RESULTS AND DISCUSSION

All the patients showed evidence clinically of sound subtalar fusion. Some residual deformity persisted after one-third of all operations, and in 8 per cent the residual deformity was marked. In every case this represented inadequate correction of the original deformity, and in no instance had " over-correction " occurred.

Lateral instability—In three patients persistent deformity gave rise to instability which was clinically apparent and required an appliance for its control.

Eight feet arthrodesed in good position (15 per cent of the total, if the pantalar operations are excluded) showed some compensatory increase in lateral movement of the talus within the tibio-fibular mortise, but no patient complained either of pain or of instability. Radiographs showed some rounding of the margins of the talus, but it was noted that the operation films, when available, showed that these structural changes preceded the tarsal fusion and therefore that they did not result from it (Figs. 2 and 3).

FIG. 2

FIG. 3

Figure 2—Radiograph of ankle ten years after triple arthrodesis of the tarsus for instability of the foot. Note the rounding of the margins of the talus. Figure 3—Review of radiographs taken at the time of operation (four years after the onset of poliomyelitis) showed that the radiographic changes were already present at that time.

Restriction of movement—Limitation of movement in the antero-posterior plane is one of the objects of Lambrinudi's operation and of Campbell's posterior bone-block. In this series it was apparent that many of the triple arthrodeses of the Dunn type showed some loss of movement compared with the normal ankle, but this was never a cause for complaint.

Osteoarthritis—The single case of advanced osteoarthritis, albeit symptomless, occurred in a woman who was operated upon at the age of forty-six, when her ankle was already subluxated and arthritic. One patient showed minor degenerative changes radiographically. He had undergone a triple arthrodesis with Campbell's bone-block twenty-one years before, and had some persistent valgus deformity with clinical instability.

THE FLAIL FOOT

The problem of the flail foot should be considered in relation to the lower limb as a whole. When control of the knee is good, a triple arthrodesis confers adequate stability of the foot and at the same time allows passive movement at the ankle. If the quadriceps is weak, some degree of equinus of the foot assists extension of the knee and a small range of ankle movement is helpful. If the quadriceps is paralysed the fusion should include the ankle joint in order further to assist the stability of the knee in extension.

Steindler (1935), basing his work on that of von Baeyer, was probably the first to show how the equinus position of the foot helps in extending the knee. The reasons for this are not always clearly understood and it will be helpful to restate them here (Figs. 4 to 6). If all the muscles below the hip are paralysed, extension of the knee is secured by the centre of gravity of the body acting in front of the plane of the knee joint, provided 1) that the gluteus maximus is strong enough to prevent the knee from going forward by increased flexion in the hip; and 2) that the tibia is not allowed to come forward through a dorsiflexion

movement of the ankle. Any effective power in the soleus will maintain the foot in equinus; acting from the periphery as the fixed point, when the foot is on the ground, contraction of this muscle will carry the tibia backwards and thus extend the knee (Fig. 5). If there is no effective power in the calf, the action of gravity in extending the knee is aided by fixation of the ankle in slight equinus (Fig. 6). Pantalar arthrodesis combines this purpose with

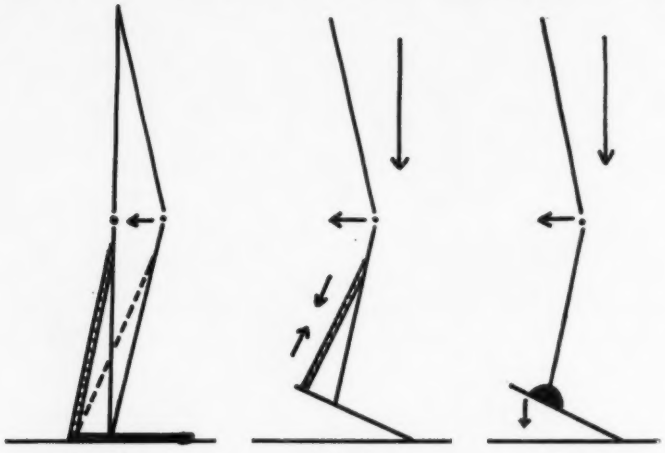

FIG. 4 FIG. 5 FIG. 6

The effect of muscle-controlled or fixed equinus upon extension of the knee (modified from Steindler, after von Baeyer). Figure 4—Normal action of soleus as an extensor of the knee with the foot on the ground. Figure 5—Soleus as a fixator of the foot in equinus. Figure 6—Rigid equinus, showing effect of body weight in extending the knee. (Vertical arrows represent body weight, horizontal arrows direction of movement of the knee joint.)

control of lateral movement in the tarsus. A small degree of genu recurvatum further assists stability in extension, but when operation is undertaken on the growing child allowance must be made for the tendency for this to increase.

Seventeen cases of flail foot were studied, in eight of which the patient had been treated by triple arthrodesis. In three cases in which there was adequate control of the knee the results were satisfactory, but of the other five, with associated paralysis of the quadriceps, all but one showed a flexion contracture of the knee, requiring an appliance for its control.

One patient had been treated by triple arthrodesis and fusion of the knee. His stability enabled him to undertake ladder work in a naval dockyard, but the limb was unwieldy and a knee-jointed appliance would probably have been more satisfactory.

The remaining eight patients, six of them with paralysed quadriceps, had undergone pantalar arthrodesis. The average length of follow-up was nineteen years. All the results were satisfactory. In those patients without quadriceps control, sound fusion had been achieved with the foot plantigrade and in slight equinus, so that the knee was encouraged to extend passively as the heel came to the ground, a mechanism which was assisted by a small degree of genu recurvatum. Four of these patients walked confidently without the aid of appliances.

CONCLUSIONS

Tarsal fusion for poliomyelitis is performed predominantly upon young people. It is therefore important to know whether it will stand the test of time, and, in particular, whether the neighbouring joint of the ankle is able to bear the increased strain thrown upon it.

From the cases reviewed it seems reasonable to conclude that degenerative changes in the ankle joint do not ensue during the twenty years after operation. Provided that varus

or valgus deformity is adequately corrected, a compensatory increase in the lateral mobility of the ankle is not accompanied by pain or clinical instability, and some reduction in antero-posterior movement may not be undesirable.

Capener (1956) noted the lack of association of poliomyelitis and osteoarthritis of a related joint, even when grossly unstable: this observation demonstrates the essential part played by muscular forces in the causation of osteoarthritis. While these facts are well recognised, the particular point of this paper is to stress that fixation of a given joint in the lower extremity does not have a harmful effect on the one above, especially the ankle in relation to the foot. In this series the number of patients with a pantalar fusion in the presence of a paralysed quadriceps are few, but their ability to control the knee in extension is in striking contrast to those whose ankle joint was not included in the fusion. It was also noticeable that slight genu recurvatum was much to be preferred to a flexion contracture.

SUMMARY

1. Sixty feet operated upon either by triple or pantalar tarsal fusion for instability after poliomyelitis were re-examined ten to twenty-four years later.

2. After triple fusion with preservation of the ankle joint there was a striking absence of late osteoarthritis of the ankle, and only a low incidence of troublesome lateral instability of the ankle. The results were generally good provided the patient had reasonable power of extension of the knee.

3. Triple arthrodesis for completely flail foot in patients without active muscle control of the knee was often disappointing, so far as the limb as a whole was concerned, because of a persistent flexion deformity of the knee which usually necessitated the wearing of an appliance.

4. The results of pantalar arthrodesis for the flail foot were satisfactory. When this operation was performed (with the foot in slight equinus) in patients who lacked active extension of the knee it helped to stabilise the knee in walking by encouraging hyperextension.

I wish to thank Mr Norman Capener, under whose care most of these patients had been, for his guidance in the preparation of this paper. Many of the patients reviewed, although living in the Exeter area, were treated at the Mount Gold Hospital, Plymouth.

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PRIMARY INTERNAL FIXATION IN OPEN FRACTURES OF THE TIBIAL SHAFT

The Problem of Wound Healing

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This paper presents the results of the treatment of eighty consecutive open fractures of the shafts of the tibia and fibula by primary internal fixation and wound closure. It emphasises the risks involved and shows that this method must be used only when there is every indication that the wound will heal by first intention.

The tibia and fibula present special problems which are not seen at other sites because the skin of the lower part of the leg forms a tight envelope around muscle and bone, with little subcutaneous tissue and a circulation that is easily impaired. For these reasons incisions and wound flaps must be planned with care, and suturing of the wound under tension must be avoided to allow the skin to heal free from vascular deficiency.

The care of the skin in the treatment of open fractures is of paramount importance, and the incision must be in correct relationship both to the wound and to the fracture, and should not traverse skin that has been bruised or has doubtful circulation; dead and devitalised tissue must be excised and the wound closed with healthy skin edges carefully apposed without tension.

In civilian practice, conditions for internal fixation of open fractures are ideal when the interval between injury and operation is short, because the quick transport of the patient to hospital allows the prompt management of shock. However, many surgeons have abandoned the use of internal fixation because of the unfortunate complications often encountered. In my opinion internal fixation may be safely employed if patients are suitably selected and if there is a careful technique of wound closure.

TABLE I

THE TREATMENT OF 210 FRACTURES OF THE TIBIAL SHAFT FROM JANUARY 1950 TO JUNE 1956

Open fractures	115
Internal fixation and primary wound closure	82
Primary wound closure only	31
Primary amputation	2
Closed fractures	95
Internal fixation	95

CLINICAL MATERIAL AND METHOD OF STUDY

Table I gives details of the clinical material. All the patients were treated at the Derbyshire Royal Infirmary. During the period reviewed ninety-five closed but unstable fractures were also treated by open reduction and internal fixation. The two patients who had amputations had severe crush injuries. Two out of the eighty-two patients with internal fixation for open

fractures have not been included further in this series because they could not be traced. Nine patients in the same group who were unable to attend for examination completed questionnaires, and five more, from both groups of open fractures, who died from other causes long after their discharge from the out-patient clinic, were also included in this study, as their records at the time of discharge were complete and indicated satisfactory healing of the wounds and bones. The operations were performed by seventeen different surgeons, most of whom were residents under training. The data were obtained by direct observations during treatment, from records, and from personal examination of the patients in both the open and closed fracture groups.

Soft-tissue damage varied from clean puncture wounds to severe lacerations with skin and muscle contusion from crush injuries. Because of this variation, and in order to obtain a more accurate assessment of the results of treatment, it is necessary to grade open fractures

TABLE II

INTERNAL FIXATION AND PRIMARY WOUND CLOSURE IN EIGHTY OPEN FRACTURES OF THE TIBIAL SHAFT

	Male	Female	Total
Number of patients	61	19	80
Average age in years	33·5	41·7	37·6
LEVEL OF FRACTURE			
Lowermost third	39	10	49
Middle third	21	4	25
Uppermost third	4	2	6
METHOD OF FIXATION			
Screw	13	6	19
Plate	47	14	61
TYPE OF ACCIDENT			
Motor cycle	27	2	29
Hit by car or motor cycle	14	9	23
Industrial or farming	10	2	12
Falls	5	6	11
Mining	5	—	5
SEVERITY OF WOUND			
Grade 1	11	1	12
Grade 2	47	16	63
Grade 3	4	1	5

according to the severity of the soft-tissue damage. This grading may also be of great assistance in deciding the correct treatment, because it is a practical guide to the severity of the injury.

The following classification appears to be a convenient and practical method of grading soft-tissue damage in open fractures, but it is realised that it is approximate and variable. *Grade* 1: Puncture wounds " from within " or small lacerations up to about one inch in length with no loss of skin and minimal muscle damage. The wound is usually excised in the line of the exposure incision and primary closure of the wound presents no difficulty. *Grade* 2: Larger wounds over an inch in length with contusion of the adjacent skin of variable degree. Some muscle damage requiring debridement but allowing safe wound closure after excision of the margins and exposure of the fracture, perhaps with the use of local plastic procedures. *Grade* 3: Severe crush injuries with extensive damage to the skin and muscles, especially in the anterior compartment. Primary wound closure, after debridement, is difficult and often impossible.

OPEN FRACTURES TREATED BY PRIMARY INTERNAL FIXATION

The details of the eighty traced consecutive fractures of the shaft of the tibia and fibula treated by internal fixation are given in Table II, which also shows the type of accident causing the injury. The majority were moderately severe open fractures (Grade 2), and more than half occurred in the lowest third of the tibia and fibula. The plates used in sixty-one patients were mostly of the slotted type; screws only were used in the others.

Associated injuries in other parts of the body occurred in twenty-six patients (32 per cent). Some delay in surgical treatment was due to head injuries in eight patients, and to the treatment of shock in fourteen patients. The average interval between admission and operation was about five hours. In thirty-nine patients the wound was longitudinal or oblique and it was excised in the line of the exposure incision. In twenty-one patients the wound was more or less transverse; most of these wounds were lengthened by extension of their ends proximally and distally; in the remainder the incision was made at an angle to one corner of the wound. In eighteen patients, exposure was effected through a straight or slightly curved incision away from the original wound, and in two patients the incision crossed the wound. In seventy-two of the eighty patients direct wound closure was possible. In eight patients local flaps were necessary to effect adequate skin cover of the tibia; five of these were bipedicled flaps fashioned by a release incision being placed medially or laterally, and three were rotation flaps.

In all cases prophylactic treatment with antibiotics was begun soon after the patient was admitted, and tetanus antitoxin was given routinely. Most patients (sixty-two) received penicillin parenterally in four-hourly or six-hourly doses of 300,000 units, and the remainder received a combination of penicillin (300,000 units every four hours) and streptomycin (half to one gramme twice daily) for seven to ten days after operation. External fixation by a long leg plaster applied over wool and a crepe bandage was used in all except five patients. Of these, three had plaster immobilisation delayed until two weeks after operation; in another a Thomas's splint was applied because of associated open fractures of the femur and patella of the same leg; the last patient, whose leg was not immobilised in plaster, had infection of the wound and a radiograph taken two weeks after operation showed angulation of the plate.

Although variations in technique were unavoidable among the various surgeons, the procedures employed were generally similar and closely followed the principles of thorough wound debridement, reduction of the fracture and internal fixation by Vitallium or stainless steel plates or screws. The aims were to strip the periosteum as little as possible, to use catgut only if absolutely necessary, to close the wound with as little tension as possible, and to apply a plaster over thick layers of gauze and wool. The foot was elevated about two feet above the bed. The plaster and dressings were changed and the sutures removed about two weeks after the operation. In the event of pyrexia, with persistent throbbing pain at the fracture site, the wound was inspected through a window cut in the plaster.

RESULTS OF TREATMENT OF OPEN FRACTURES

There was primary healing of the wound in sixty-five open fractures (81 per cent) treated by this method. Satisfactory bony union by primary intention occurred in seventy fractures (87 per cent) and eventual bony union in seventy-six (95 per cent).

In an analysis of the complications encountered, it was considered important to take into account the severity of each fracture. A significant conclusion concerning the management of these fractures may be drawn if the incidence of complications in the less severe type (Grade 1) is materially lower than that in Grade 2 or Grade 3.

Infection, skin loss, non-union and excessive scarring were the main complications encountered, in that order of frequency (Table III).

Infection—Infection was classed as superficial or deep. Superficial infection implied some separation of the edges of the wound and a short period of discharge. If the bone was involved the infection was classed as deep (Lottes, Hill and Key 1952).

Superficial infection—Loss of skin at the wound edges of varying degree preceded the onset of superficial sepsis in all the five patients included in this group. In three, this was due to ulceration of a patch of contused skin adjacent to the wound which at the time of the operation had been thought to be viable. In the remaining two, tension at the suture line contributed to wound breakdown.

Skin replacement by free grafting was carried out in two patients. In all, infection cleared up within a few days to a few weeks and eventual recovery was complete.

Deep infection—Serious infection occurred in eight patients, all of whom had been treated by fixation by a plate. The onset of sepsis with involvement of the underlying bone marked the beginning of a regrettable series of events that included long periods of hospitalisation and multiple operations for the treatment of sequestration, chronically discharging sinuses, non-union and unstable scarring.

In the three case histories in this group that follow, the fractures were the result of severe crush injuries to the leg with severe soft-tissue damage (Grade 3).

TABLE III

RESULTS OF PRIMARY INTERNAL FIXATION AND WOUND CLOSURE IN EIGHTY OPEN TIBIAL FRACTURES

Primary healing of wound				65 (81%)
Primary healing of bone				70 (87%)
Complications	Grade 1	Grade 2	Grade 3	Total
INFECTION				
Superficial . .	—	4	1	5
Deep . . .	—	5	3	8
SKIN LOSS				
Slight (marginal) .	1	4	—	5
Moderate . .	—	2	—	2
Extensive . .	—	—	3	3
NON-UNION . .	—	10	—	10
UNSTABLE SCARRING	—	6	3	9

CASE REPORTS

Case 1—A fifty-five-years-old postman was hit by a lorry in December 1952 and admitted with severe open fractures of the lower third of the left tibia and fibula. There was a large lacerated wound, running obliquely downwards from the posterior part of the leg to about two inches above the ankle on the medial side. The proximal fragment of the tibia was protruding through the wound, and there was extensive muscle damage. Treatment consisted in debridement of the wound, internal plate fixation, wound closure and immobilisation in plaster. Penicillin (300,000 units four-hourly) was prescribed.

There was moderate pyrexia, and, five days later, on inspection of the wound, a large patch of necrotic skin was seen over the front of the middle of the tibia. There was some discharge from the upper part of the wound from which a heavy growth of penicillin-insensitive staphylococcus aureus (coagulase-positive) was cultured. Other organisms cultured were diphtheroid and coliform bacilli and micrococcus tetragenous.

Deep sepsis resulted in bone necrosis; and a series of operations, including sequestrectomies, a cross-leg flap and a sliding bone graft were undertaken. Up to the time of this investigation, however, there were still discharging sinuses on the antero-medial aspect of the leg.

Case 2—A thirty-nine-years-old miner sustained severe open fractures of the lowest third of the left tibia and fibula when his leg was trapped between two wagons in August 1953. There were two

extensive lacerations over almost the entire length of the anterior part of the leg, with considerable contusion of the skin and damage to the muscles of the anterior compartment. At operation, a great amount of devitalised muscle tissue was excised, and adequate fixation was effected by plating. After the closure of the wounds the leg was immobilised in a long leg plaster, and penicillin (300,000 units every four hours) and half a gramme of streptomycin twice daily were given.

Four days later there was widespread skin necrosis in an area between the two anterior lacerations. The wound appeared dry and there was no clinical or bacteriological evidence of infection. About three weeks later, however, and after excision of the sloughs, staphylococcus aureus (coagulase-positive) sensitive to both penicillin and streptomycin was obtained from the wound. Bacterium pyocyaneus was also present.

In spite of all attempts at skin replacement and control of infection, considerable bone necrosis developed and a below-knee amputation was performed.

Case 3—A thirty-nine-years-old man was admitted in June 1954 with multiple injuries from a road accident. He had sustained comminuted open fractures of the uppermost third of the left tibia and fibula, with a laceration about four inches long on front of the leg, skin contusions, and extensive damage to the anterior tibial muscle. After excision of the non-viable part of this muscle, an attempt was made to restore its continuity by catgut sutures. Internal fixation was carried out by plating, and after closure of the wounds the leg was immobilised in a plaster. Penicillin was given in doses of 600,000 units twice daily.

Wound healing was complicated by gross infection with profuse discharge from the medial wound. Penicillin-insensitive staphylococcus aureus (coagulase-positive) was cultured from the wound. Bony union was achieved after long periods of antibiotic therapy, removal of the plate, sequestrectomy and replacement of unhealthy and scarred skin with a cross-leg flap.

In the first two patients, estimation of the viability of the skin at the time of operation was too optimistic. Loss of skin was extensive and appeared to precede the onset of infection. In the last patient, wound healing was complicated by severe suppuration from bacterial decomposition of devitalised muscle. Suture of muscle under tension may have been the main reason for this.

In the remaining five patients with deep infection, the open fractures were classed as moderately severe (Grade 2).

In one a transverse wound about three inches long was found over the fracture site in the uppermost third of the left tibia and fibula. The fracture was exposed through a straight incision running longitudinally at right angles to the wound. Later, loss of skin occurred on the medial side of the proximal part of the incision and was soon followed by infection. Bony union occurred only after removal of the plate and replacement of the unhealthy skin by a cross-leg flap.

In the second, operation was performed about sixteen hours later for unknown reasons; in the third, the leg was not immobilised in plaster after the operation and a radiograph taken two weeks later showed angulation of the plate.

In the last two patients a low-grade type of " delayed " infection with the formation of discharging sinuses and sequestration appeared several weeks after healing of the open wound. In both patients the responsible organism was a penicillin-sensitive staphylococcus aureus (coagulase-positive), and both had received penicillin prophylactically. It is possible that this sensitivity to penicillin was responsible for preventing the development of an overt clinical infection early in the post-operative period.

Both patients were treated by removal of plates and sequestrectomies, and, in one, an unstable scar was replaced by a local skin flap.

Skin loss—This is a serious complication of open fractures and may lead to wound infection, exposure of bone and sequestration. It may result from direct damage to the skin at the time of the accident or excessive tension at the suture line after closure of the wound. Occasionally it may occur in an ischaemic part of a skin flap.

Loss of skin interfered with primary healing of the wound in ten patients (12 per cent) in this series. It varied in extent; in five patients it was slight and occurred at the edges of the wound. Of the remaining five patients, two developed skin necrosis at the site of the open

wound with exposure of the bone and the formation of granulating ulcers. Deep sepsis followed in one, and both were treated by removal of plates and replacement of unhealthy scarred skin by cross-leg flaps. In the remaining three patients loss of skin was extensive and, in two of these, preceded the onset of deep infection.

Infection occurred in seven patients, in three of whom the underlying bone became involved (Table IV). These patients have already been described.

Direct damage to the skin at the time of the accident was thought to be responsible for skin necrosis in five patients. In three of these the loss of skin was extensive and occurred on the front of the leg. In one there was skin contusion near the open wound, and in another there was contusion of an area of skin medial to the incision.

Excessive tension at the site of wound suture caused some loss of skin at the wound edges in four patients. Ischaemia of the flap occurred in one patient, medial to the point of

TABLE IV

INFECTION COMPLICATING TREATMENT OF EIGHTY OPEN TIBIAL FRACTURES BY INTERNAL FIXATION AND WOUND CLOSURE

Superficial infection occurred in 5 patients	
Severity of injury:	
Grade 1	0
Grade 2	4
Grade 3	1
Preceded by skin loss: in 5 patients	
Slight (marginal)	3
Moderate	1
Extensive	1
Deep infection occurred in 8 patients	
Severity of injury:	
Grade 1	0
Grade 2	5
Grade 3	3
Preceded by skin loss: in 3 patients	
Slight (marginal)	0
Moderate	1
Extensive	2

crossing of a longitudinal incision and a transverse wound; progress was further complicated by deep infection.

Non-union—This occurred in ten patients (12·5 per cent). In all but one the fractures were in the lowest third of the tibia and fibula, and most of them (eight) were treated by plate fixation. Skin loss complicated wound healing in four patients in this group, and in one of these superficial sepsis occurred. In another infection was severe and involved the underlying bone.

Internal fixation was considered inadequate in two cases, and in another two premature removal of the plaster may have contributed to non-union. Considerable bone loss at the site of the fracture, with a consequent gap between the fragments, was the main factor responsible for non-union in one patient.

Bony union was achieved in six patients after bone grafting. Of the remaining four, three developed fibrous union and are able to get about reasonably well and have declined further operation. One patient is still under treatment after failure at bone grafting because of persistent sepsis.

Excessive scarring—This troublesome complication is a late result of skin loss and wound infection. It may vary from excessive formation of adherent scar tissue with skin pigmentation to unstable scarring with chronic indolent ulceration. A common complaint is of a dull ache on walking and a feeling of tightness in the lower leg.

Nine patients were classed under this heading, and in seven of them deep or superficial infection had complicated wound healing. Skin loss had occurred in four and had preceded the onset of infection.

In six patients scarring was unstable with the formation of recurrent slowly healing ulcers. One patient developed a gravitational ulcer on the medial side of the lower leg several months after complete healing of the wound. He responded well to treatment by recumbency and local applications. In the remaining two patients there was excessive scarring in the region of the wound at the front of the leg, adherent to the underlying tibia, but without any ulceration.

Plastic operations for the replacement of scar tissue were advised in eight patients and performed in all but one. These included cross-leg flaps in four, rotation flaps in two, and a dermis graft in one patient.

CLOSED FRACTURES TREATED BY INTERNAL FIXATION

Infection occurring after open reduction and internal fixation of a closed fracture should indicate some error in surgical technique. A study of the incidence of sepsis and other complications in a consecutive series of closed fractures treated by internal fixation by approximately the same number of surgeons, during the same time, should serve as control for the assessment of the results of treatment of open fractures by primary internal fixation.

FIG. 1

Gravitational ulcers and skin pigmentation on the concave side of the exposure incision eighteen months after plate fixation of a comminuted open fracture of the lowest third of the left tibia in a patient with longstanding venous insufficiency.

Of ninety-five patients with closed unstable fractures of the shaft of the tibia and fibula operated upon by fourteen surgeons during six and a half years (January 1950 to June 1956) there were two cases of deep infection (2·1 per cent).

In one patient skin loss occurred in a patch of contused skin medial to the incision which was thought to be viable at the time of operation. The wound was soon infected and the sequence of discharging sinus, sequestration and delayed union followed. Excision of this area of skin of questionable viability might have averted this complication. The second patient was readmitted with a low-grade osteitis and non-union several months after plate fixation of an unstable fracture of the lowest third of the tibia. A swab taken after removal of the plate yielded penicillin-insensitive staphylococcus aureus, and the case records showed that the patient received adequate doses of parenteral penicillin after the operation. Since penicillin-insensitive staphylococci are resistant to the drug from the beginning, it is possible that in this case a low grade sub-clinical infection had developed soon after operation and persisted until signs and symptoms of osteitis became manifest. The associated occurrence of non-union would lend support to this supposition.

In two other patients there was mild superficial wound infection which cleared up within a few days without causing loss of skin.

One patient, aged thirty-five, who had superficial varicosities in both legs, was treated by plate fixation for comminuted fractures of the lowest third of the left tibia and fibula. The

tibial fracture was exposed through a curved incision and, although the wound and fractures healed well, he returned eighteen months later with gravitational ulcers on the concave side of the incisional scar. Extensive pigmentation, often associated with venous insufficiency, had also developed in an area medial to the incision (Fig. 1).

OPEN FRACTURES TREATED WITHOUT INTERNAL FIXATION

Thirty patients admitted with thirty-one open fractures of the shaft of the tibia and fibula were treated by debridement, wound closure and immobilisation in plaster. Comparison of the results in this group with those obtained in open fractures treated by internal fixation was not possible because of the many variables involved. The method generally adopted for the treatment of open fractures was that of internal fixation whenever possible and desirable. This group therefore was formed by patients who were either too ill to undergo prolonged surgery or whose fractures were considered on mechanical grounds to be unsuitable for internal fixation. Moreover, most of the wounds (60 per cent) were classed as Grade 1 puncture wounds " from within " or small lacerations, while the number of patients treated by internal fixation in Grade 1 was much smaller (15 per cent).

About a third of the fractures (ten) occurred in patients unfit for early surgery because of delayed recovery from shock with associated multiple injuries, head injuries or senility. The majority (eighteen) of fractures were treated without internal fixation for mechanical reasons. In eleven there was minimal displacement and the fractures were considered stable, and in three there was gross comminution of the fragments. In four the fractures were too low in the shaft to permit satisfactory fixation. In three fractures no definite reason for not employing internal fixation was recorded.

Further manipulation was required in twelve patients to correct persisting angulation of the fragments. In the remainder the position obtained at the time of operation was accepted. There was one case of deep infection in a Grade 3 severe open fracture, with extensive muscle damage and skin loss. Mild superficial infection delayed wound healing in two patients. Skin loss occurred in five more patients and was attributed to tension at the site of suture in three, to contusion of skin in one, and to pressure of the underlying incompletely reduced proximal fragment in another.

DISCUSSION

Winnett Orr (1921*b*) called attention to the necessity of early reduction and immobilisation of open fractures. He asserted later (1939) that peace-time injuries often do worse than those sustained in battle because of the different methods employed. Trueta (1943) treated more than a thousand open fractures, most of them gunshot injuries of the limbs, under war conditions in Spain, with exceptionally good results by the use of primary reduction, immobilisation in plaster, wound drainage by calico gauze or other single packs and infrequent dressings. Further experience from the last war and the more recent tornado disasters in the United States has established the fact that healing of the wound without infection can be achieved in most cases by early adequate debridement, delayed closure of the wound and plaster immobilisation under antibiotic therapy. Primary wound closure is definitely hazardous and will inevitably result in a high incidence of infection, loss of skin, scarring and non-union.

Antibiotic therapy, improved surgical technique and the development of metals suitable for internal fixation have stimulated the recent trend for more ambitious results in the treatment of peace-time fractures. Davis (1948) attributed the improved results in a series of 150 consecutive open fractures, of which fifty-five were fractures of the tibia, to the compression dressing, the immediate covering of the surface defect with skin or split-skin graft and to immediate or delayed complete reduction and metallic fixation. In converting an open fracture into a closed one, within a few hours of injury, tissues, whether bone, muscle or skin, are restored to as near normal as possible.

Hampton (1955) emphasised the important role played by adequate reduction of the fracture in the prevention of wound infection. With the fragments held in good position, dead space in which contaminated blood clot and wound exudate can collect is avoided, pressure of fragments against the undersurface of the skin that might cause necrosis does not occur, wound margins are more easily approximated without tension, and repeated damaging efforts at reduction are unnecessary.

At the discussion that followed the presentation of twenty-four open fractures treated by internal fixation and primary wound closure (Zadik 1953) at the annual meeting of the British Orthopaedic Association in October 1952, Sir Reginald Watson-Jones expressed the general consensus that the use of internal fixation was justified only when it seemed certain that primary wound healing could be obtained. The main difficulty, however, lies in selecting the type of open fracture that will be suitable for internal fixation and in ensuring healing of the wound by first intention. Since open fractures constitute the commonest emergencies requiring prompt surgical treatment in any accident service, and are usually dealt with late at night by the resident staff on duty, the problem is a real one. To abandon the method completely, on the grounds that it may be hazardous, is to deprive some patients of the combined benefits of internal fixation—that is, accurate reduction, firm apposition and good immobilisation—and those of primary wound healing. On the other hand, the enthusiastic closure of open fractures after internal fixation of the fragments has often led to disastrous results. It is hoped therefore that more specific criteria will be available to the surgeon who is confronted with this difficult problem.

It is apparent from the analysis of the results obtained in this series that the method of treatment in the group of open fractures associated with extensive soft-tissue damage (Grade 3) should be similar to that adopted for battle injuries. Despite early surgery, ideal hospital conditions and antibiotic therapy, the incidence of infection will remain high. On the other hand, when the wound is small and clean and muscle damage minimal (Grade 1) the results have been excellent. The only complication encountered in the twelve patients classed under this grade was slight marginal skin loss in one case. It should be stressed that exposure of the deeper layers of the wound and debridement, in fractures of this grade, should be as careful and complete as for the more severe type of open wounds. In a patient with a small puncture wound, a sizable piece of glass was found embedded on the lateral aspect of the tibia at considerable distance from its site of entry.

Of the sixty-three fractures classed in Grade 2 with moderately severe wounds, five were complicated by deep sepsis and in another four some transient superficial wound sepsis occurred. In most of these wounds skin loss of varying degree preceded the onset of infection, and this appears to be the commonest cause of wound sepsis in civilian fractures treated by primary wound closure. Infection, chiefly by the staphylococcus, develops in the superficial layers of the wound and may later involve the underlying bone. Suppuration is minimal and, because sepsis is not present at the beginning, systemic manifestations appear late after operation and run a relatively mild course. Antibiotic therapy may further mask the signs of infection.

Sepsis in an open fracture may also occur as the result of suppuration from bacterial decomposition of devitalised soft tissues, mainly muscle and blood clot (Hampton 1955). A staphylococcal infection is usually present and the systemic manifestations, with the temperature showing the characteristic pattern seen in suppuration, appear on the third or fourth day after operation. Sepsis here is deep from the beginning and purulent discharge from the wound is profuse. Infection of this type occurred in three of the eight patients studied.

In civilian fractures, invasion of living tissue by bacteria primarily or secondarily implanted in the wound, of which gas gangrene and haemolytic streptococcus are examples, is not common, and has not occurred in any of the patients in this series.

Penicillin alone cannot be relied upon as an adequate prophylactic antibiotic. In all the eight patients complicated by deep sepsis, staphylococcus aureus (coagulase-positive) was cultured from the wounds. In two, proteus, pyocyaneus and coliform bacilli were also present. In six patients the organisms proved insensitive to penicillin and in four to aureomycin. Resistance to streptomycin was demonstrated *in vitro* in two cases and to chloromycetin in

FIG. 2

Comminuted open fracture of the mid-shaft of the tibia treated by plate fixation. The incision has been carefully planned to avoid contused skin and to facilitate wound closure.

FIG. 3

The same patient as in Figure 2 twelve days after plate fixation. The wound has healed by first intention.

none. The organisms present in the wounds at the time of admission are seldom known, but penicillin and streptomycin act synergistically against most staphylococcal strains even though *in vitro* the results may indicate resistance to either. A combination therefore of systemic penicillin and streptomycin in adequate doses should provide an effective and safe prophylactic cover for most wounds. These drugs should be started in the emergency room and the first

dose should be large. Chloromycetin and the other recently introduced antibiotics should be given only when specifically indicated.

If infection occurs, the presence of metal may prevent wound and bone healing and considerably increase the risk of osteomyelitis. Early removal of the plate and screws, preferably through a window in the plaster to avoid loss of position and ensure uninterrupted immobilisation, together with free drainage of the wound and specific antibiotic therapy, may still avert the onset of serious bone infection.

The importance of safe skin closure cannot be overemphasised. In seven of the ten patients in whom skin loss occurred wound healing was further complicated by infection. The site and direction of the wound and the condition of the adjacent skin are factors of great importance if primary wound closure is contemplated. Incisions are carefully planned to avoid contused skin and facilitate wound closure (Figs. 2 to 4). Crossing of the wound by the incision is avoided, and transverse or oblique wounds are extended by proximal and distal incisions at their opposite corners. Longitudinal wounds are excised in the line of the

FIG. 4

Four months after operation the same patient as in the preceding figures has union of the fracture and an excellent scar.

incision (Figs. 5 and 6). Skin economy in wound excision, particularly in the lowest third of the leg, may prevent unnecessary plastic procedures and permit closure without tension. The wounds in this series were closed by direct approximation in seventy-two patients and by local plastic procedures in the remaining eight. From the incidence of skin loss, it is apparent that in some cases an optimistic view was taken of the viability of the skin. Direct contusion of the skin, tension at the suture line, and flap ischaemia were the main causes of skin loss in that order of frequency. Davis (1948) considers the most frequent cause of failure of healing by first intention to be an attempt to preserve questionable skin.

Excessive tension may be avoided by the use of local plastic procedures. A free split-thickness skin graft may be applied over the defect, but as most wounds in open fractures of the tibia lie on the medial aspect of the leg, with exposure of bone, this procedure is undesirable in most cases. The transfer of bipedicled flaps over skin defects overlying the tibia is a more useful procedure and is commonly used. It is important to draw the parallel incision as far from the wound as possible in order to avoid circulatory embarrassment of a narrow bridge of skin, and to cover the defect left by the release incision by free split-thickness skin grafts.

Finally, a local rotation flap may be used for the larger and more circumscribed type of skin defects. It should be widely based and planned at the beginning of the operation.

Patients with long-standing venous insufficiency and varicosities offer poor skin for any operation in the leg. Extensive pigmentation, skin fibrosis and gravitational ulcers may develop later in consequence of impaired venous return. Fractures of the lower limbs sustained by such patients should be treated with as little surgery as possible. Examination of both legs at the time of admission for any signs of venous insufficiency is a routine that may prevent the occurrence of unnecessary complication. Finally, the use of a compression bandage to prevent the collection of exudates and blood in the subcutaneous tissue and to prevent further

FIG. 5

Open fracture of the lowest third of the tibia treated by plate fixation. The wound was excised in the line of the incision which was extended proximally and distally from the ends of the wound.

FIG. 6

The same patient as in Figure 5 showing a well healed wound ten days after operation.

oedema, the application of plaster-of-Paris to give additional rest to the injured tissues, and the insistence of leg elevation for several days after operation, are all points of importance in ensuring sound wound healing.

In conclusion, the surgeon who is confronted with the problem of the management of an open fracture of the tibia should ask himself the following questions: " Is internal fixation necessary? Are fixation and primary wound closure permissible? Have I the necessary experience to deal with it? "

The answer to the first question lies in the radiological appearance of the fracture. That to the second may be furnished by careful inspection of the wound and adjacent skin.

SUMMARY AND CONCLUSIONS

1. Eighty consecutive open fractures of the tibial shaft were treated by primary internal fixation and wound closure. Wound healing was complicated by deep infection in eight patients (10 per cent) and by skin loss of varying degree in ten (12·5 per cent).

2. Careful selection of patients on the basis of associated soft-tissue injuries is urged. A simple method of grading open fractures by the appearance of the wound and adjacent skin and the effectiveness of wound closure is suggested. If internal fixation is indicated on mechanical grounds, the nature of the soft-tissue injury should be the deciding factor in the choice of the method of treatment. In the less severe (Grade 1) fractures internal fixation and wound closure may be safely employed. In the severe (Grade 3) injuries, primary wound closure with or without internal fixation should be avoided. Moderately severe (Grade 2) fractures should be carefully assessed and treated by internal fixation and wound closure only if primary wound healing is confidently expected.

3. Wound healing by first intention requires, in addition to adequate debridement of the deep layers of the wound, careful approximation of healthy wound edges without excessive tension. An adequate knowledge of skin-plastic procedures is essential to achieve this.

4. A combination of systemic penicillin and streptomycin in adequate doses is a safe and effective prophylactic antibiotic for use in the treatment of open fractures.

I wish to thank Mr R. G. Pulvertaft and Mr E. W. O. Adkins for their help in preparing this paper. I also thank Mr J. S. Fayers for the clinical photographs and the staff of the Record Department of the Derbyshire Royal Infirmary for their co-operation and assistance.

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CONGENITAL POPLITEAL WEBBING IN SIBLINGS

A Report of Two Cases

RANDELL CHAMPION and J. C. F. CREGAN, MANCHESTER, ENGLAND

Severe congenital web formation in the limbs and neck is uncommon, and often hereditary. Shun-Shin (1954), reporting a large Mauritian family with congenital antecubital webbing in three generations, made a comprehensive review of the literature on this subject in general, and the two siblings with extensive popliteal webbing described in this paper resemble the patients reported by Wolff (1889) (one knee only); Kopits (1937) (both knees affected in four patients); Edwards (1938) (both knees affected in one patient); and Aberle-Horstenegg (1938) (both knees affected in one patient).

CASE REPORTS

Case 1—A first child of normal parents was admitted to the Duchess of York Hospital for Babies at the age of one week. The sex was indeterminate, as the genitalia showed both male and female characteristics, but was later determined to be female. She had a cleft of the soft palate and two congenital sinuses of the mucous membrane of the lower lip. She had skin webs extending from the region of the ischial tuberosities to the heels, the knees being held flexed 100 degrees. The skin of the webs appeared normal, but at the free margin of each web a hard, inelastic subcutaneous cord two millimetres thick extended from the ischial tuberosities to the inner side of the insertions of the calcaneal tendons, causing a rigid inversion of the heels and feet (Fig. 1). The toes were maldeveloped; only three toes were present on each foot, one being a true hallux and one a syndactyl of two digits; four metatarsals were present.

As it seemed most unlikely that the hard subcutaneous cord would ever stretch, operation was undertaken on the right leg when the child was two weeks old. The skin web of the popliteal fossa, extending from the ischial tuberosity to the heel, was adjusted by Z-plasty extending from the limits of the webbing. When the skin was reflected there was a satisfactory exposure of the underlying structures. The subcutaneous fibrous cord was detached from the ischial tuberosity and from the fibrous tissue above the heel, and the loose fibromuscular and fatty tissue of the web dissected out. The sciatic nerve and its branches were found lying free in the length of the web, half-way between the free edge and the apex, and well superficial to the normal muscular structures. The popliteal vessels were normally situated deep in the popliteal space. The hamstrings and calf muscles appeared normal except for some merging of their fibres with the fibromuscular layers of the web, both medially and laterally (Fig. 3). These fibromuscular septa joined the cord at the free edge of the web, forming a thin hood over the sciatic nerve, so that the sciatic nerve may be said to have been covered by muscular tissue. The septa were excised, but the knee could then be straightened only by 30 degrees. The posterior tibial branch of the sciatic trunk was divided at the ankle to minimise the bowstring tension on the sciatic nerve; it was supposed that this tension might produce a high sciatic palsy while the deformity was later being corrected. The Z-plasty was closed in the usual manner. Healing was uneventful, apart from a small area of skin necrosis at the apex of the lower flap which necessitated supplementary skin grafting. After the operation 70 degrees of contracture remained, from capsular and musculo-tendinous resistance.

A similar operation was carried out on the left leg at the age of four months, the anatomical findings and operative steps being the same except that the posterior tibial nerve was not divided.

FIG. 1

FIG. 2

Case 1. Figure 1—The webbing is seen to extend the whole length of the leg. Figure 2—One year after operation the extension of the knee lacks only 20 degrees.

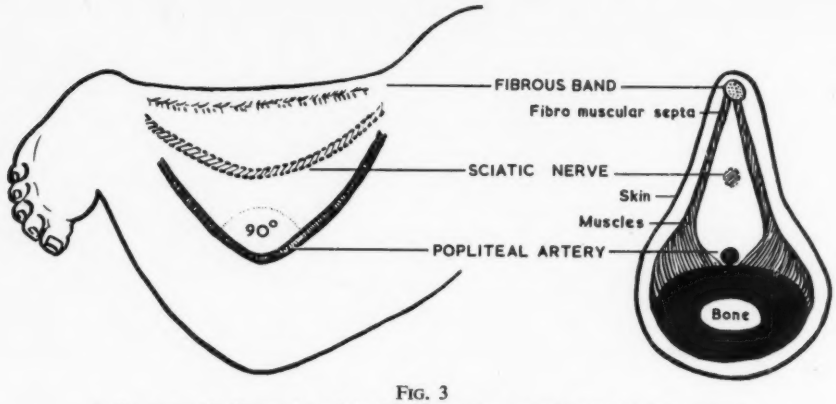

FIG. 3

A diagrammatic illustration of the findings at the operations in the two patients.

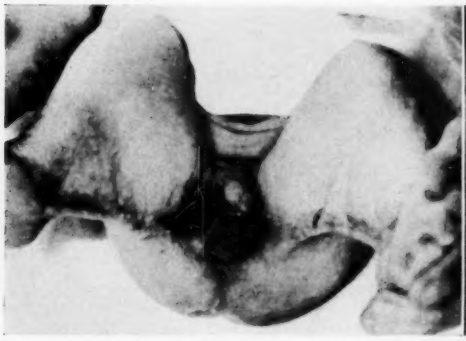

FIG. 4

FIG. 5

Case 2. Figure 4—The webbing and the fibrous band is clearly shown. Figure 5 shows the deformity of the feet in the same infant.

After the operations, correction of the flexion deformities of the knees and feet was easily effected by serial moulded plasters and later by physiotherapy. At six months of age the cleft in the soft palate was closed by the standard two flap V–Y method. The sinuses of the mucous membrane of the lower lip were excised a month later.

The child is now two years old and can stand unaided. Active and passive extension of the knees is within 20 degrees of normal (Fig. 2). There is no paralysis in the left leg, and it is plain that, unfortunate as the position of the nerves appears at operation, they can accommodate themselves to the gradual corrective extension of the knees.

Case 2—One year later a second child, a boy, was born to the same parents (Fig. 4). The same deformities in the mouth, legs and feet were present as had been present in his sister, except that the left foot had one hallux and two pairs of syndactylous toes, and the right foot had one hallux and no other toes (Fig. 5). The treatment was also the same; operation was undertaken between the fourth and sixth months of life, the posterior tibial nerve being left intact in both legs. The gain in passive knee extension on the operation table was again only about 30 degrees from the initial 100-degree contracture, but a steady improvement has been obtained in the range with simple stretching and physiotherapy. Nine months after operation passive extension is now 45 degrees from full, and is still increasing in both knees. There is no evidence of weakness in the muscles supplied by the sciatic nerve.

SUMMARY

The early management of bilateral congenital popliteal webbing in a brother and sister is described. There was no familial history of webbing, but the maternal grandfather had a hare-lip. Although the sciatic nerve is so unfavourably placed in the web, correction of the flexion deformity can apparently be carried out safely after plastic repair of the skin by Z-plasty and excision of the fibrous web cord alone, without causing a traction paralysis. These cases appear to be unique in that the patients are siblings of different sex with identical congenital abnormalities of bilateral webbing, cleft palate and fistulae of the mucous membrane of the lower lip.

Our thanks are due to the Department of Medical Illustration, Wythenshawe Hospital, for their help.

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A CASE OF CONGENITAL ARTERIOVENOUS ANEURYSM INVOLVING THE FEMUR

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This rare condition is being described for the unintentionally dramatic way in which it was discovered and, in a sense, there is also a Cautionary Tale. If there is a moral to the story, it is this: Always put a stethoscope on a suspected bone tumour and look at the radiographs more than once.

So far as I know, there is no description of a non-traumatic arteriovenous aneurysm involving, or arising in, one of the long bones.

Congenital arteriovenous aneurysms are not uncommon and are fully described in the medical literature. Various authors have described different lines of treatment, but basically it consists in radical excision of the aneurysm and arteriovenous fistulae, more especially so if there is a progressive apical systolic murmur indicating a progressive left heart failure. When the condition affects an arm or a leg there is usually an increase in the length and size of the affected limb, and this causes more disability when the leg is affected. The discrepancy in length in the young can be overcome by epiphysial arrest, if the vascularity of the area of operation allows it.

FIG. 1

FIG. 2

Figure 1—Initial plain radiograph. Figure 2—Arteriograph showing the arteriovenous fistula involving the bone.

These unusual congenital deformities are ascribed to a defect in the vascular mesoderm at an early stage of development; so there is no reason why the nutrient vessels to a bone should not be affected.

CASE REPORT

A girl aged nine, an only child, complained of intermittent pain in the left thigh for six months. There had been no injury. Up to the time of onset she had enjoyed normal health, and she was still able to play games and to lead a full life at school. The pain kept her awake at night, especially after exercise, and later she started to limp and to get slightly out of breath. There was no relevant abnormal family history.

Examination—The child walked with a slight limp affecting the left leg. She indicated the middle third of the left femur as the site of the pain. There was local tenderness at that point, with slight thickening: the girth of the thigh at its mid-point was increased by one inch. Movements at the hip and knee were full and painless. I did not measure the length of the limbs or use a stethoscope at this initial examination.

A radiograph showed a multiloculated cortical erosion of the middle third of the postero-medial part of the left femur (Fig. 1). The appearance was that of a benign tumour. Nevertheless the clinical picture was suspiciously malignant; so biopsy was advised, with a provisional questionable diagnosis of monostotic fibrous dysplasia.

Operation—I exposed the femur through a lateral incision, unmindful at the time that the radiograph showed the part involved to be the postero-medial aspect of the femur. This providential mistake proved the true nature of the pathology to my naked eye and forefinger in a direct, as well as an indirect, sense. For, on making a small opening in the cortex of the normal looking femur, I noticed an underlying membrane which had the glistening appearance of the lining of a bone cyst. The fluid in the cyst was bright red, a finding that baffled me at the time. However, thinking it was an unusual type of bone cyst, I ruptured the membrane with a curette and was greeted by a torrential gush of bright red blood. This was no venous oozing, but massive arterial bleeding. The tip of my forefinger fitted the hole nicely, whereupon

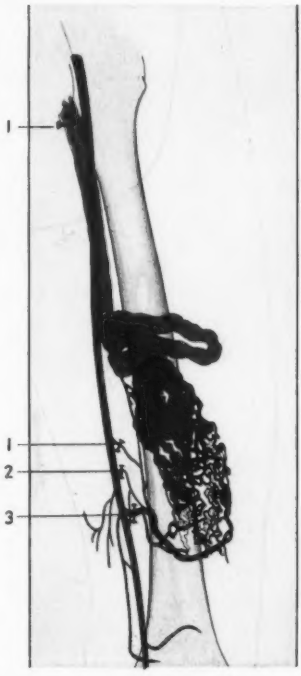

FIG. 3

FIG. 4

Figure 3—Tracing of arteriograph showing some of the blood vessels that were ligated. Figure 4—Plain radiograph three years after ablation of the arteriovenous fistulae.

all bleeding stopped dramatically, and it was then I first felt the strange fluttering of the arteriovenous fistula. The slightest release of pressure from the hole allowed recurrent arterial bleeding under considerable pressure. In fact I was now dealing with a strange situation: that of a bony pipe flowing with arterial blood under pressure, and with a half-inch hole in the pipe. It badly needed a bung of some sort, and I was considering a sterile cork when the third tube of Horsley's wax finally plugged the hole. After stitching up the wound I put a stethoscope on the thigh and we all listened to the strange cavernous rumblings of an arteriovenous aneurysm involving bone, at the same time noting that the patient had a fairly pronounced apical systolic murmur.

Progress and further treatment—The girl made an uneventful recovery from the operation and later a femoral arteriograph was performed by my colleague, Dr B. M. Maxwell. This showed

the multiple ramifications of the arteriovenous anastomosis involving the femoral artery and vein, with obvious involvement of the bone at the site of the multiloculated area of erosion (Fig. 2). Mr D. Ll. Griffiths, whose advice I sought, suggested as complete an excision as possible because: 1) there were signs of left heart failure; 2) the femur was structurally weaker at the affected point and might break with disastrous results; and 3) the plugging of the hole in the femur might not be as permanent as we hoped. If this excision did not prove successful an amputation might be necessary.

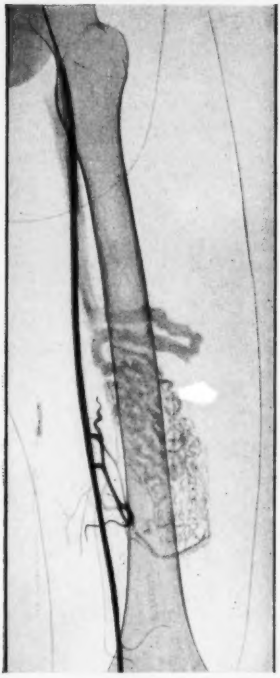

FIG. 5

Tracing of arteriograph three years after ablation of the arteriovenous fistulae. The faint shadow shows the area originally involved.

With the aid of Mr A. B. Birt, my surgical colleague, I proceeded to ligate all the anastomosing arteries from below upwards, starting just above the knee (Fig. 3). It is surprising how many have to be ligated, and this time it was not until we were well into the groin, having ligated five arteries below the inguinal ligament, that we found a large artery overlying an enormously distended vein which seemed to be the main culprit. After this artery and the underlying vein were excised the thrill stopped with dramatic suddenness, and the limb became silent. The anaesthetist noticed that the systolic murmur had also disappeared.

The circulation of the left leg appeared normal at the conclusion of the operation and there was normal pulsation in the popliteal and femoral arteries.

Recovery was uneventful and the child was allowed up three weeks later. At this stage she had a slightly increased systolic thrumming over the left femoral artery, just below the inguinal liagment to the medial aspect of the thigh, but otherwise sounds were normal.

She has been back at school for four years and serial radiographs showed that the affected area of the femur filled in rapidly and has appeared almost normal for three and a half years, except for the hole that I made. This hole, presumably, is still plugged with Horsley's wax, and unlikely to disappear (Fig. 4).

When I last examined her, four years after the operation, her legs were equal in length. The left thigh was still larger in girth by two and a half inches than the right one. She walks without a limp and leads a normal active life. Examination of the heart shows no abnormality.

DISCUSSION

The diagnosis is not in question, but how I might have arrived at the diagnosis more easily certainly is. Those who advocate arteriography for all bone tumours would be satisfied, and this may be the answer, because in competent hands it provides additional evidence without risk. However, after this experience I consider that auscultation of suspected bone tumours should be an important part of the routine clinical examination. It is interesting that the localised changes in the femur could not be distinguished radiologically from cortical monostotic fibrous dysplasia, and the dramatic improvement in the appearance of the bone after ablation of the aneurysm was striking.

There is no doubt that there was a minor arteriovenous fistula not involving bone, because there was one localised area of thrumming just above and lateral to the knee. This

area has been tender, but recently all tenderness has disappeared and the bruit has stopped, indicating a spontaneous obliteration of the fistula.

At one time, two years after the operation, this child showed an increase of an inch in the length of the left leg, but the limbs are now equal in length, showing that growth is taking place normally. Although she will be under observation for some years to come, she is no longer living on the edge of a catastrophe such as might have befallen her in the event of a pathological fracture of her femur.

A further femoral arteriograph (Fig. 5) was performed by Dr B. M. Maxwell three years after the operation and this showed a nearly normal vascular picture and no evidence of an arteriovenous aneurysm over the outer aspect of the leg. The tracing shows the original area of anastomosis faintly outlined to demonstrate the extent of ablation. This may be because the arterial supply comes from an enlarged gluteal or aberrant obturator or profundus femoris artery, beginning above the inguinal ligament and therefore not filled with the radio-opaque medium.

SUMMARY

1. A case of congenital arteriovenous aneurysm involving the left femur, with dangerous cystic changes in the shaft of the bone, is described.

2. After ligation of the anastomosing fistulae the radiological appearance of the femur became normal.

My sincere thanks are due to my colleagues, Mr A. B. Birt and Dr B. M. Maxwell, for their help and assistance. I also am grateful to Mr D. Lloyd Griffiths for his valuable advice on the treatment of this patient.

CYSTIC DEGENERATION OF THE PERONEUS BREVIS TENDON

D. E. ROBERTSON, PEEL HOSPITAL, GALASHIELS, SELKIRKSHIRE

Tendons that are enclosed in synovial sheaths commonly escape the degenerative lesions affecting collagenous tissue. The following case shows marked degenerative changes in the substance of the peroneus brevis tendon. It appears that no similar lesion has been recorded.

CASE REPORT

Four years ago the patient, a woman of fifty-four years, had slipped on a grassy slope, sustaining a severe inversion strain of the right ankle which was treated by immobilisation in a below-knee plaster for six weeks and then by strapping for two weeks. Radiographs taken the day after the injury showed no bony damage.

She continued to have pain and swelling over the peroneal tendons both at rest and on walking, and eventually sought further advice. On clinical examination a tender, firm, non-fluctuant swelling could be palpated in the line of the peroneal tendons. Antero-posterior and lateral radiographs of the ankle were negative; an antero-posterior view taken in forced inversion showed no significant tilt of the talus.

FIG. 1
Appearance of the tendon after opening the synovial sheath.

Exploration of the swelling was undertaken. The synovial sheath of the peroneus brevis tendon was thickened and contained a little free fluid, its visceral surface being shaggy and yellowish. The appearance after the synovial sheaths were opened is shown in Figure 1. The tendon of the peroneus brevis was of normal size near its origin from the muscle belly, but in its lower two-thirds it was greatly thickened and nodular. It was excised from the musculo-tendinous junction to its insertion into the fifth metatarsal base. On transection it contained numerous little cystic spaces which were separated from each other by narrow fibrous septa (Fig. 2).

FIG. 2
Transverse sections of the tendon.

FIG. 3
Cystic spaces separated by fibrous septa. (×60.)

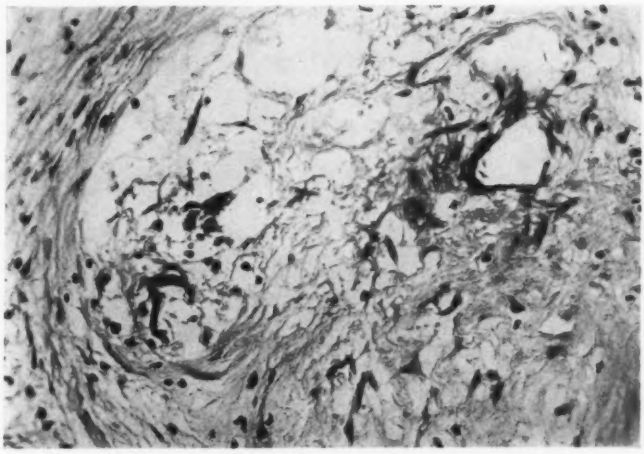

FIG. 4
An active focus of degeneration. (×250.)

Microscopically the swelling and nodularity were seen to be due to mucoid or gelatinous degeneration of the fibrous collagenous tissue with the formation of cysts filled with clear, colourless mucoid material. Due to the breaking down of their adjacent walls many of the smaller cysts had coalesced to form larger ones up to a centimetre in diameter. They have walls of fibrous tissue lined by a single layer of flattened cells which are fused with the surrounding tissues (Fig. 3). The high power photomicrograph (Fig. 4) shows an area whose features reveal the early active stage of the condition. There is a focus of fibroblasts showing degenerative changes, swelling of the cytoplasm, rupture of the cytoplasmic membrane and the formation of clear spaces which presumably contain the mucoid fluid. Pyknosis of the nuclei, infiltration of a few round cells and granular debris can also be seen. Transverse sections of the tendon at various levels revealed the degenerative process to be active in its proximal part, whereas distally it appeared inactive.

COMMENT

Since this lesion was immediately preceded by a single well remembered strain of the ankle, trauma may have been the main factor in initiating the intratendinous degeneration, although it is interesting that the accompanying peroneus longus tendon appeared normal to the naked eye. The thickening of the synovial sheath is thought to be secondary to the swelling of the tendon itself. Microscopically this rare condition is indistinguishable from those common cystic swellings that arise on the dorsum of the wrist and foot, and from a lateral semilunar cartilage. These swellings are also frequently attributed to injury (Ogilvie 1957).

I wish to thank Dr J. D. McGregor of the Pathology Department, and the staff of the Photomicrography Department, University of Edinburgh.

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A CASE OF REPLACEMENT OF THE UPPER END OF THE HUMERUS BY A FIBULAR GRAFT REVIEWED AFTER TWENTY-NINE YEARS

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From the Royal Infirmary, Edinburgh

In recent years, after resection of the ends of long bones, increasing use has been made of acrylic resins and stainless steel for replacement, to the exclusion of the bone-grafting procedures described by earlier workers.

Rovsing (1910), after resecting the proximal two-thirds of the humerus for round-cell sarcoma in a man aged twenty-six, used a graft of the proximal end of the fibula to replace the defect. Two months after operation the patient was said to have free passive movements and to be able to feed himself. Albée (1915) advocated the use of tibia or fibula to replace the proximal end of the humerus or femur removed for benign new growths, and supported this by describing Murphy's case of a girl aged ten with osteitis fibrosa cystica of the upper two-thirds of the humerus. The whole of this area was resected and replaced by a transplant from the tibial crest, placed within the periosteal tube of the humerus. Almost complete regeneration of the humerus had occurred within eight months after operation. Morison (1914) used a fibular graft to replace the upper two-thirds of the shaft of the humerus, excised for chondrosarcoma. In this case the head of the humerus was retained, but failed to unite to the proximal end of the graft. In spite of this the patient was able to abduct the arm 90 degrees three years after the operation. Skillern (1920) described the case of a girl of seventeen in whom he had excised the upper two-thirds of the humerus for osteogenic sarcoma and replaced it by fibula, but there was no follow up. A further case was reported by Behrend (1930) in a woman of fifty with chronic diffuse osteomyelitis involving the upper two-thirds of the humerus: a year after operation she had a good range of movement. The longest follow-up recorded was that of Schauffler (1926) who reported the case of a girl of fifteen who was treated by fibular transplantation for bone loss from septic arthritis of the shoulder. Five years later she was married and able to care for her house and children.

German workers performed much pioneer work on joint transplantation and arthroplasty using both autografts and homografts during the early part of this century. Borelius (1914) performed the operation for giant-cell tumour in a man aged twenty-five who had a good range of movement four and a half months later, though the deltoid was atrophic. Lexer (1925) undertook fibular replacement of the upper humerus on four occasions with excellent functional results. He illustrated this by a radiograph showing a soundly united fibular graft, three months after operation, but he did not report the follow-up of his cases in detail.

Fibular grafts have been used frequently in recent years for the replacement of radial and tibial defects (Hey Groves 1917, Eikenbary 1928, Miller and Phalen 1947), but there are few reports of their use in the replacement of the humerus.

CASE REPORT

A railway worker aged nineteen was admitted to the charge of Mr John Struthers at the Royal Infirmary, Edinburgh, in December 1929. He complained of increasing pain and stiffness in the right shoulder region during the six months before admission. On examination, there was a rounded swelling which appeared to involve the head and upper two inches of the shaft of the humerus. The radiological appearance was that of giant-cell tumour involving the head of the humerus. Biopsy confirmed the diagnosis of giant-cell tumour, but the histologist suggested that the tumour was " not entirely benign."

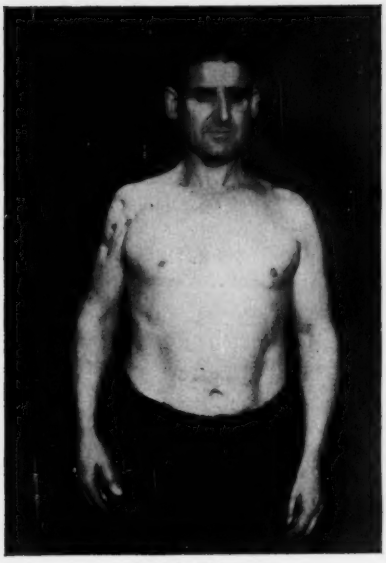

FIG. 1

FIG. 2

Figure 1—Photograph showing the rather unsightly scar and sinus, and the extent of shortening. Figure 2—The arm in abduction. The range is increased by 30 degrees when the arm is rotated laterally.

FIG. 3

The radiographic appearance. In spite of the anterior displacement of the graft, about 40 degrees of scapulo-humeral movement is possible.

At operation on December 26, 1929, the shoulder joint and upper shaft of the humerus were exposed through an incision in the delto-pectoral cleft. Six inches of the proximal end of the humerus were resected, with preservation of the deltoid insertion. A corresponding length of the head and shaft of the right fibula was removed; the lower end of this graft was fitted

securely into the medullary cavity of the humerus, and the articular aspect of the head lay against the glenoid cavity. The joint capsule was not sutured. The shoulder was immobilised in a plaster spica with 90 degrees' abduction for four weeks. The plaster was then replaced by a poroplastic splint which held the arm in slight abduction, but permitted forearm and wrist movement. Active abduction was not permitted " for a considerable time," but it was noted in 1932 that he was able to abduct the arm to 90 degrees, and although he had a small discharging sinus he was working as a taxi driver.

Present condition—The opportunity to assess the patient's present condition arose when he was readmitted to the Royal Infirmary in January 1958 for excision of a semilunar cartilage. He now drives a three-ton lorry and handles heavy loads without difficulty. A small sinus has persisted (Fig. 1), but is kept clean with soap and water. Powerful abduction and flexion at the shoulder joint are possible to 130 degrees (Fig. 2). Medial rotation is full, but there is 20 degrees' restriction of lateral rotation. Radiographs confirmed that there is a fair range of scapulo-humeral movement, though the transplanted fibular head lies in front of the neck of the scapula (Fig. 3). There has been considerable thickening of the graft distal to the head. A small sequestrum is present on the lateral side.

DISCUSSION

This twenty-nine-year follow-up after resection of the proximal end of the humerus with fibular replacement supports the claims made by Lexer and others as to its value. The cases recorded in the literature were not followed up for a period long enough for a true assessment of the results. The longest follow-up was that of Schauffler (1926) whose patient was able to perform all her household duties satisfactorily five years after operation.

The present range of application of the operation is probably small. Early workers were prepared to undertake local resection and grafting for certain early cases of malignant tumours of bone (Byrne 1917), a procedure which would not be contemplated to-day. Furthermore, some of the reported cases were performed for chronic osteomyelitis, a condition which is now much less common. Perhaps the most important field of application is in the treatment of giant-cell tumour of bone. The decision to carry out a local resection would be influenced by such factors as were indicated by Campbell (1949), who advised resection 1) when the functional disability would be slight (as in the upper fibula, metatarsals, the head of the radius) and 2) when bony destruction was so extensive that complete curettage was not possible. It would also depend upon the biopsy findings. Geschickter and Copeland (1949) stated that resection should be reserved for recurrence of the tumour after curettage and cauterisation.

The technique of the operation is well described in the orthopaedic text-books (Campbell 1949). It is recommended that the insertion of the biceps femoris into the head of the fibula should be preserved with the graft, so that the shoulder cuff tendons may be sutured to it. This was not done in the patient reported here, and it is to be noted that the head of the fibula has failed to remain in the glenoid cavity. In spite of the persistent dislocation, the functional result has been excellent and the patient has not had to restrict his activities.

Choice of material for replacement—If replacement is contemplated after resection of the proximal end of the humerus a choice has to be made between a prosthesis and a bone transplant. Acrylic resin has on one occasion been used recently in this department to replace the proximal end of the humerus invaded by a giant-cell tumour which had recurred after radiotherapy. The prosthesis remained in good position within the glenoid cavity, but the patient did not regain any scapulo-humeral movement. The excellent functional result obtained in the present case would suggest that fibular replacement should always be considered when resection of the proximal half of the humerus is contemplated.

SUMMARY

1. A case of giant-cell tumour of the proximal end of the humerus treated by resection and fibular grafting twenty-nine years ago is reported. An excellent functional result has been maintained.
2. The literature is reviewed and the results claimed by earlier workers are noted.
3. The present field of application of the operation is probably in cases of advanced or recurrent giant-cell tumour of bone.

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A FRACTURE PLATED BY SIR WILLIAM ARBUTHNOT LANE IN 1912

C. C. JEFFERY, EXETER, ENGLAND

A few months ago an active gentleman of seventy-seven years attended hospital complaining of a " tennis elbow " syndrome. He stated that he had had an elbow fracture treated by Sir William Arbuthnot Lane as a private patient at Guy's Hospital in 1912, and produced sepia prints showing the fracture before and after treatment by plating (Fig. 1). The former print was clearly marked with the date (September 25, 1912) and with the name of Sir Arbuthnot Lane.

The patient had had no further trouble with the elbow until recently when he developed symptoms of " tennis elbow," with marked tenderness over the lateral epicondyle. Elbow and forearm movements were full. A new radiograph showed very minor arthritic change in the elbow and almost complete disintegration of the distal halves of the screws (Fig. 2).

The symptoms were relieved by an injection of procaine and hydrocortisone about the lateral epicondyle. The plate and screws were not removed as the patient was anxious to avoid any operation that was not essential.

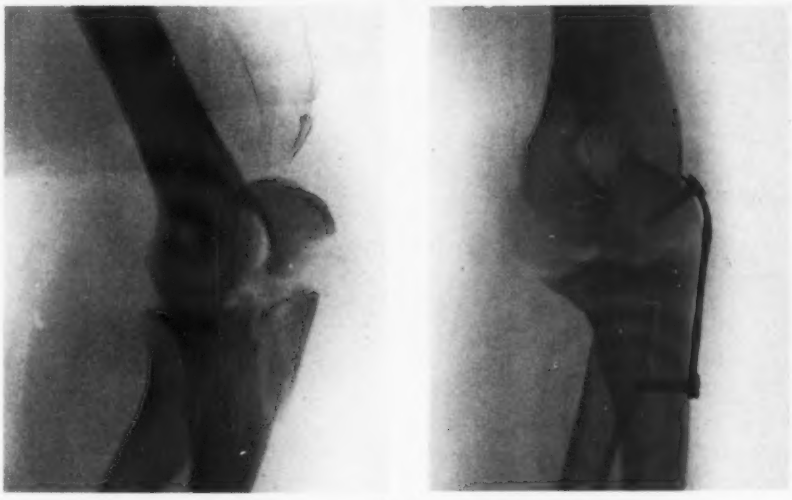

FIG. 1

Comminuted fracture of the olecranon dated September 25, 1912, before and after plating by Sir William Arbuthnot Lane.

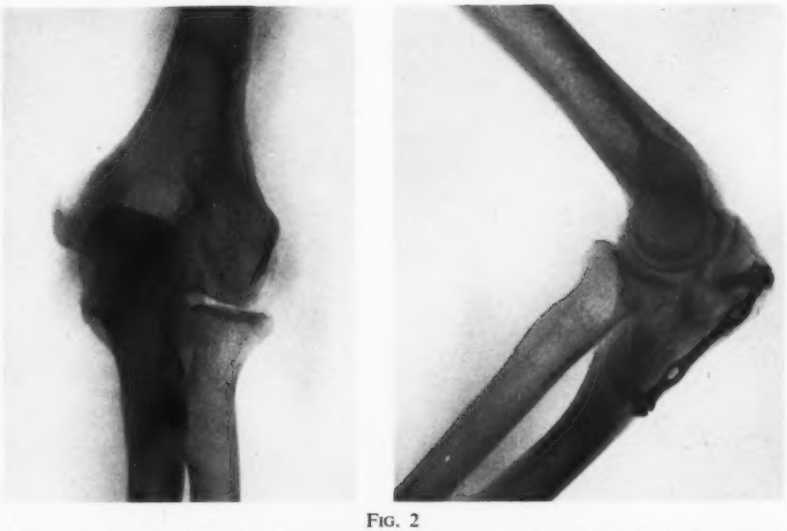

FIG. 2

Recent radiographs of the same elbow more than forty-five years later, showing disintegration of screws and minor arthritic change in the elbow, which nevertheless had full function.

A patient who has had a metallic implant for over forty-five years is a rarity, especially when the implant was inserted by so distinguished a pioneer of internal fixation in the treatment of fractures.

JIVE FRACTURE OF THE FIRST RIB

R. BROOKE, WORTHING, ENGLAND

Stress fractures of the first rib may occur from " rock and roll " and jiving. The fracture is a vertical one at the junction of the posterior and middle thirds of either the right or left first rib, behind the attachment of the scalene muscles. It occurs in young adults, and follows the energetic movements associated with the so-called dancing popular at the moment with 'teenagers, called jiving.

The onset is acute, but may be delayed. The complaint is of pain in the region of the thoracic inlet on the affected side, with pain radiating down the back of the arm to the elbow: also pain in the left pectoral region. It is probably caused by the pull of the scalene muscles together with a severe rotation strain associated with the swirling movements of the arms, either right or left, carried out with great force in this type of dancing.

No treatment seems to be necessary except the wearing of a sling for six or eight weeks, with avoidance of jiving.

CASE REPORTS

Case 1—A youth of eighteen, a typographer, gave a history of an acute onset of pain in the left upper thoracic vertebrae after jive dancing. The pain radiated down the back of the left arm to the elbow: it was relieved by hot poultices.

FIG. 1
The fracture in Case 1.

On examination the posture of the patient was poor: there was tenderness in the region of the supraclavicular triangle, with limitation of movement of the left shoulder in all

directions. A radiograph showed a vertical fracture of the first rib at the junction of the posterior and middle thirds, without displacement (Fig. 1).

FIG. 2
The fracture in Case 2.

Case 2—A girl of eighteen complained of pain in the right shoulder region after jive dancing.

On examination there was limitation of movement of the right shoulder joint in all directions. A radiograph showed a vertical stress fracture at the junction of the posterior and middle thirds of the right first rib (Fig. 2).

OSSIFYING CHONDROMA OF METACARPAL BONE AND PHALANGES

G. BLUNDELL JONES, EXETER, ENGLAND

This case is presented because of its most unusual features and similarity to melorrheostosis.

A boy aged fourteen complained of pain and increasing deformity in his right middle finger. The finger had always been shorter than normal and limited in flexion, but, until the last two or three years, it had been of the same thickness as the others. It was apt to get in the way and to be knocked frequently, and, after such minor injuries, swelling would appear but not go down again.

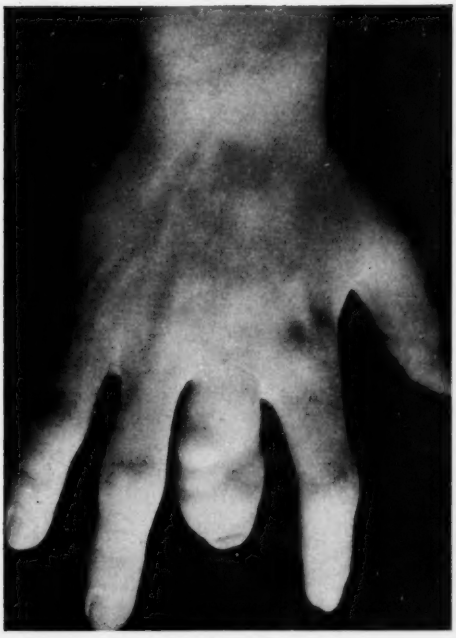

FIG. 1

FIG. 2

Photograph and radiograph of the hand, showing the dense masses surrounding the shaft of the third metacarpal bone and the phalanges of the middle finger.

FIG. 3

Photograph of half specimen.

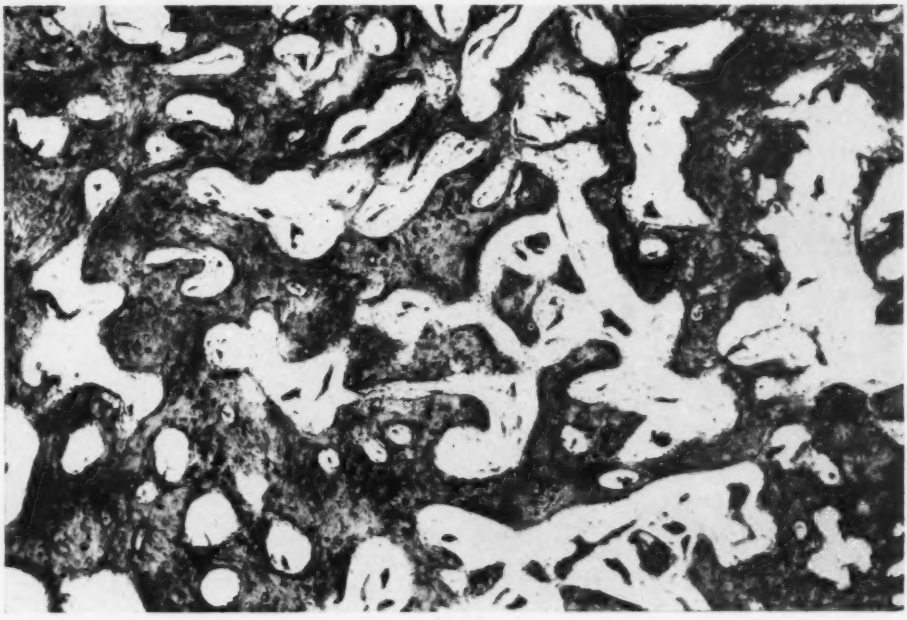

FIG. 4
Section from part of the specimen showing new bone trabeculae. (H. and E., ×40.)

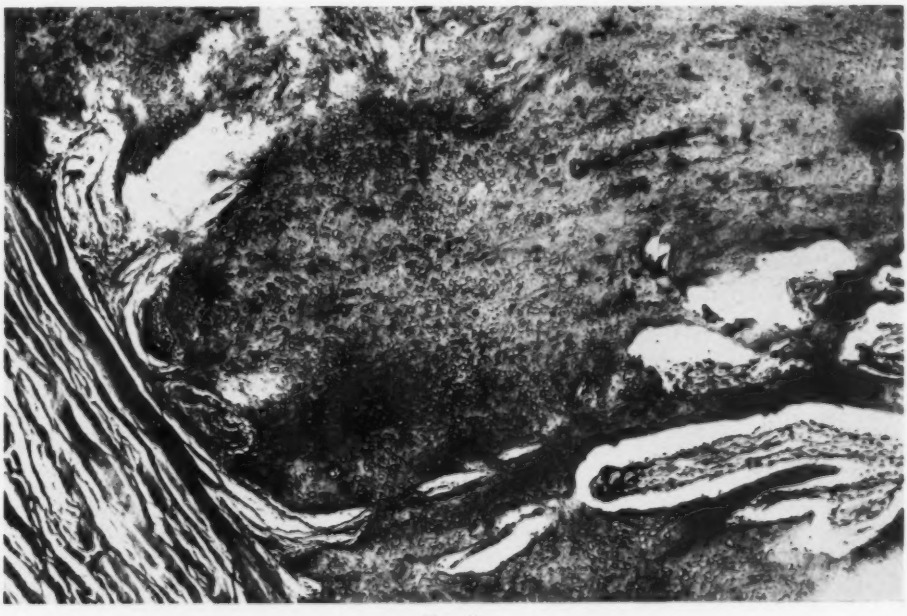

FIG. 5
Another part of the specimen, showing cartilage at the margin of new bone. (H. and E., ×40.)

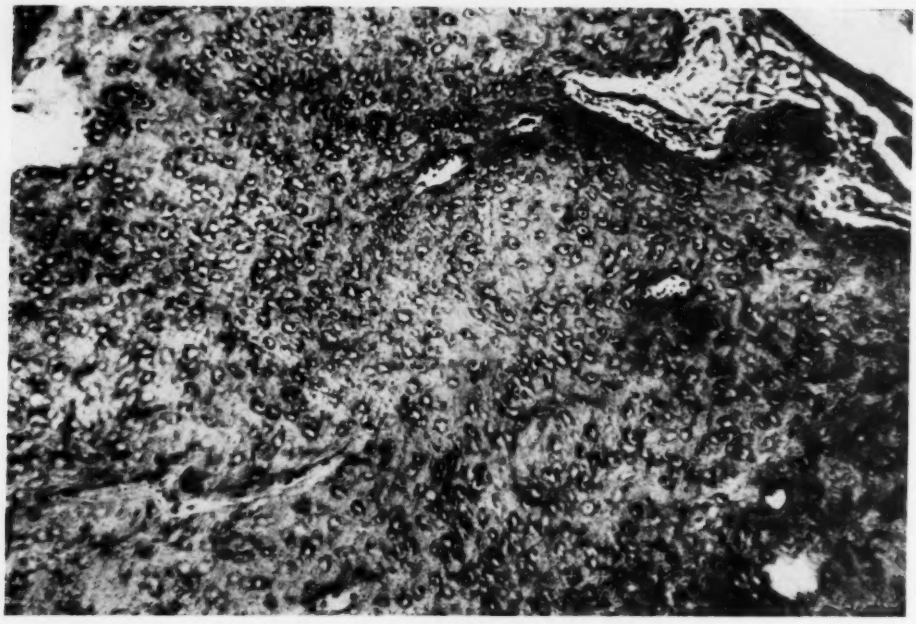

FIG. 6
A typical area of cartilage. (H. and E., ×80.)

Examination of the finger showed the deformity illustrated (Fig. 1), with practically no movement in the interphalangeal joints and about half the normal range at the metacarpo-phalangeal joint. The finger was tender to pressure but showed no inflammation and the skin over it was normal. Radiographs revealed dense masses surrounding the shafts of the metacarpal bone and phalanges (Fig. 2). The other bones of the hand and right arm were normal.

Treatment—Amputation of the whole ray was performed, with carpo-metacarpal disarticulation (Fig. 3). The function and appearance of the hand are now satisfactory.

Histological examination—Sections showed that the swelling of the phalanx was due to an irregular mass of cartilage in various stages of ossification (Figs. 4 to 6). Histologically, therefore, the picture was one of a chondromatous mass being converted into bone.

I am indebted to Dr G. Stewart Smith for the pathological report and the photomicrographs.

MULTIPLE OSSIFICATION CENTRES IN THE EPIPHYSES OF THE LONG BONES OF THE HUMAN HAND AND FOOT

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The extensive literature dealing with radiographic changes in bones during normal development is concerned principally with the time at which epiphysial centres appear and the ages at which they fuse with the diaphyses. Little attention has been paid to the appearance and form of these epiphyses soon after they have become radio-opaque. This paper directs attention to the frequent occurrence of multiple ossification centres in many epiphyses of the hand and foot.

REVIEW OF THE LITERATURE

Observations on the number of centres of ossification in an epiphysis—Serres (1829, 1838) saw two and three epiphysial centres for the thumb and big toe in parts that had been dissected, and Rambaud and Renault (1864) also discovered two centres of ossification in certain phalanges and in a metatarsal bone.

With the advent of radiology there have been many observations on the first appearance of epiphyses in general. Some authors, such as Pryor (1925), believe that the ossification centre starts as a pin-point of bone tissue which " gradually enlarges and approaches the form of the bone." Others believe that individual centres of ossification may appear as multiple bony nodules (Greulich and Pyle 1950; Caffey 1956; Shanks, Kerley and Twining 1939; Pyle and Hoerr 1955; Liess 1956). When the phalanges, metacarpals and metatarsals are considered in particular there is considerable divergence of opinion; most authors who found more than one centre of ossification believed that this was rare, or the exception to the rule. Puyhaubert (1913) found single centres in phalanges; double centres have been described by Behrendsen (1897), by Davies and Parsons (1927), by Greulich and Pyle (1950) and by Brailsford (1953). Köhler and Zimmer (1956) regarded multiple centres of ossification as rare. It is interesting, however, that many illustrations in the literature depict, without comment, more than one centre in the various long bones of the hands and feet (Bruce 1907, Bertwistle 1924, Flory 1936, Meschan 1951, Venning 1956).

Multiple centres of ossification have been described by Serres (1829, 1838), Hasselwander (1903), Redding (1926), Buxton and Knox (1927), Francis and Werle (1939), Liess (1955) and Caffey (1956); but Sawtell (1931) alone considered the frequency of the occurrence and this only in metatarsals.

Observations on the fusion of multiple centres of ossification in an epiphysis—There are few details in the literature on the time elapsing before fusion of the centres occurs; the time factor is referred to as " temporary " (Liess 1956), " a few weeks " (Rambaud and Renault 1864), " rapidly " (Sawtell 1931; Shanks, Kerley and Twining 1939), " soon " (Francis and Werle 1939), " later " (Caffey 1956), " about the sixth or seventh year " (metatarsals) (Redding 1926), and " after the tenth year " (first proximal phalanx of foot) (Redding 1926). According to Caffey (1956), they fuse into " a single large bony center which may remain uneven in density and irregular on the margins for many months before it becomes uniform in density and smooth on the edges." Shanks, Kerley and Twining (1939) described rapid fusion and enlargement " into a round or oval mass of cancellous bone, which normally presents an irregular, nodular contour," but also referred to the formation of a plaque of bone " whose deep surface in many epiphyses becomes markedly notched or cogged."

Observations on the spread of ossification within the epiphysis—According to Sawtell (1931), the first centres of ossification in the epiphyses of the first metatarsal and the first proximal

phalanx of the foot appear medially and ossification spreads laterally. This is true for the first proximal phalanx in the series of children to be described here, but in the case of the first metatarsal ossification most commonly occurred laterally and spread medially.

MATERIAL AND METHODS

The findings described in this paper are based on serial radiological examinations of the hands and feet of a group of sixty boys and sixty girls, all being normal, healthy white children of British ancestry but born in Australia and living in Melbourne. They form a reasonably representative cross-section of their community from the geographic, social and economic standpoints. The children were examined at three-monthly intervals from the age of two to four years, during which time the maturation of the bones of the hands and feet is proceeding rapidly. On each visit they were carefully examined, and their general health, physique and progress were recorded by measurement and photography. The diets of the children were reviewed at six-monthly intervals and their intelligence was tested annually.

To reduce errors in the interpretation of the small shadows thrown on a radiographic film by multiple centres in an epiphysial area the radiographic technique was painstaking and standardised. All the radiographs were taken by the same technician, who employed the same methods throughout the investigation. To ensure absolute similarity of exposures, a platform was fixed to the radiographic tube at a distance of three feet from the source and at right angles to the central ray, and on this the hand or foot was positioned upon the film so that the central beam followed a direct dorso-volar and dorso-plantar course. Special care was exercised in the case of the foot to prevent flexion of the toes which distorts the shadows thrown by the phalanges. This standardisation of position permits an accurate recognition of centres soon after they become radio-opaque, and early signs of fusion can be determined with certainty.

Before each radiographic examination the hands and feet were cleansed to avoid the possibility of artefacts. Despite this, occasional films showed small indistinct shadows scattered throughout the soft-tissue areas. Since a consecutive series of films was available for each child, those shadows which neither remained constant in form and position nor matured into obvious osseous foci were eliminated from the record.

Each radiograph was assessed by two independent examiners and the findings were transferred to a progress sheet recording all the serial observations for the individual epiphyses in each particular child. After the final examination at the age of four years all radiographs were again scrutinised as a series.

A careful study of the epiphysial areas under discussion has not revealed any change equivalent to the diffuse mineralisation which occurs in some parts of the body. The multiple shadows that we are describing on the radiographs enlarged gradually within the epiphysial area but were always circumscribed. When large enough they developed trabeculae. In many of the children they have fused to form an epiphysis of conventional appearance and shape.

OBSERVATIONS

The radiograph of each metacarpal, metatarsal and phalanx was examined separately and each bone could be placed in one of the following categories.

1. No evidence of epiphysial ossification present at four years. This material was of no value in this study.

2. A single centre present in the epiphysis at the first examination at two years. Here there was no way of determining whether or not these centres represented multiple foci that had fused before the first examination, but additional centres subsequently appeared in some of these cases.

3. Multiple centres present in the epiphysis at the first examination. Some of these showed evidence of fusion within the epiphysis during the investigation.

4. No ossification present at the first examination and only one centre appearing in the course of the investigation. Here the possibility remains that these epiphyses could develop additional centres at a later age. Very few epiphyses are likely to follow this course because ossification is well advanced at four years and so it is considered that these are examples of single centres of ossification.

5. No trace of ossification present at the first examination, with multiple centres appearing in the epiphysis during the investigation.

During the examination of the radiographs it was seen that, in many children, epiphysial centres of ossification appeared as two or more discrete radio-opaque areas. This was observed much more commonly in the foot than in the hand, and more commonly in boys than in girls (Tables I to IV).

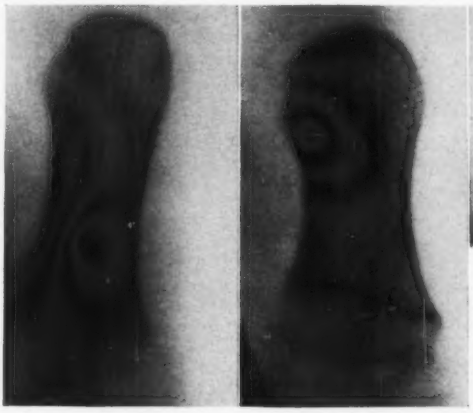

FIG. 1

FIG. 2

FIG. 3

FIG. 4

Examples of multiple ossific nuclei in the epiphyses of a first metacarpal (Fig. 1), first metatarsal (Fig. 2) and first proximal phalanges of the foot (Figs. 3 and 4).

The frequency with which multiple centres of ossification appeared, the number of such centres in an individual epiphysial area, and the sequence of events observed radiographically in these areas, were related to the shape of the epiphysial area.

The epiphysial areas associated with the shafts of the first metacarpal and first metatarsal are approximately rectangular and are thicker than any other rectangular epiphysial areas in the hand and foot. Each epiphysis commonly showed multiple ossific nuclei—sometimes as many as six (Figs. 1 and 2). In some individuals these centres gradually enlarged until they met, and then radiographically the margin of each bony centre was lost in the area of contact, and later trabeculae could be traced from one to the other.

The epiphysial area in the remaining metacarpals and metatarsals was rounded and seldom developed more than two ossific nuclei for the former and three for the latter (Figs. 13 to 16).

The first proximal phalanx in both the hand and foot has an epiphysial area which is almost linear and particularly long in the foot. These were remarkable for the large number of small ossific nuclei that were often present (Figs. 3 and 4). For example, this epiphysis had five centres in the hand in four boys, and in the foot there were six centres in ten boys, seven centres in two boys and eight centres in one boy. These centres were not necessarily all present at the one examination, fusions and additions being responsible for variations observed at individual examinations. The total number observed in any epiphysis for the period studied is given in the Tables. Fusion within this epiphysial area occurred either by

TABLE I*

THE NUMBER OF CENTRES OF OSSIFICATION THAT APPEARED IN THE LEFT HAND IN SIXTY BOYS BETWEEN THE AGES OF TWO AND FOUR YEARS

Bone	Number of centres in each boy						Total with multiple centres	Multiple centres showing some fusion	Total with no centre at first. Later	
	None	One	Two	Three	Four	Five			Single	Multiple
M. 1	3	44	11	1	1	—	13	9	17	9
M. 2	—	54	5	1	—	—	6	6	2	2
M. 3	—	58	2	—	—	—	2	2	9	1
M. 4	—	54	4	2	—	—	6	6	18	3
M. 5	—	55	5	—	—	—	5	5	23	3
P.P. 1	5	9	20	17	5	4	46	29	3	28
P.P. 2	—	58	2	—	—	—	2	1	1	1
P.P. 3	—	57	3	—	—	—	3	3	3	2
P.P. 4	—	59	1	—	—	—	1	1	1	—
P.P. 5	1	48	9	2	—	—	11	10	10	7
M.P. 2	2	56	2	—	—	—	2	2	2	—
M.P. 3	1	54	3	2	—	—	5	5	5	2
M.P. 4	2	55	3	—	—	—	3	3	3	1
M.P. 5	21	35	4	—	—	—	4	3	3	4
D.P. 1	—	60	—	—	—	—	—	—	—	—
D.P. 2	10	48	2	—	—	—	2	1	1	2
D.P. 3	3	56	1	—	—	—	1	1	1	1
D.P. 4	4	54	2	—	—	—	2	2	2	2
D.P. 5	11	47	2	—	—	—	2	1	1	2

*In Tables I to IV:—M=metacarpal or metatarsal; P.P.=proximal phalanx; M.P.=middle phalanx; D.P.=distal phalanx. The thumb, index, middle, ring and little fingers are designated by the numbers 1, 2, 3, 4 and 5 respectively.

TABLE II

THE NUMBER OF CENTRES OF OSSIFICATION THAT APPEARED IN THE LEFT HAND IN SIXTY GIRLS BETWEEN THE AGES OF TWO AND FOUR YEARS

Bone	Number of centres in each girl				Total with multiple centres	Multiple centres showing some fusion	Total with no centre at first. Later	
	None	One	Two	Three			Single	Multiple
M. 1	—	59	—	1	1	1	4	1
M. 2	—	60	—	—	—	—	1	—
M. 3	—	60	—	—	—	—	1	—
M. 4	—	59	1	—	1	1	3	—
M. 5	—	60	—	—	—	—	6	—
P.P. 1	2	43	11	4	15	12	6	5
P.P. 2	—	60	—	—	—	—	1	—
P.P. 3	—	60	—	—	—	—	—	—
P.P. 4	—	60	—	—	—	—	—	—
P.P. 5	—	58	2	—	2	2	1	—
M.P. 2	1	58	1	—	1	1	3	1
M.P. 3	1	58	1	—	1	1	2	1
M.P. 4	1	58	1	—	1	1	4	1
M.P. 5	4	56	—	—	—	—	14	—
D.P. 1	—	60	—	—	—	—	4	—
D.P. 2	1	58	1	—	1	1	21	—
D.P. 3	1	58	1	—	1	1	3	1
D.P. 4	1	59	—	—	—	—	7	—
D.P. 5	1	59	—	—	—	—	27	—

TABLE III

THE NUMBER OF CENTRES OF OSSIFICATION THAT APPEARED IN THE LEFT FOOT IN SIXTY BOYS BETWEEN THE AGES OF TWO AND FOUR YEARS

Bone	Number of centres in each boy							Total with multiple centres	Multiple centres showing some fusion	Total with no centre at first. Later	
	None	One	Two	Three	Four	Five	Six to eight			Single	Multiple
M. 1	—	3	13	18	10	14	2	57	32	2	23
M. 1	7	30	19	4	—	—	—	23	11	26	21
M. 3	16	29	12	3	—	—	—	15	4	27	14
M. 4	35	15	9	1	—	—	—	10	3	15	10
M. 5	44	11	4	1	—	—	—	5	—	10	5
P.P. 1	—	6	3	10	13	15	13†	54	47	1	20
P.P. 2	—	43	12	5	—	—	—	17	17	1	4
P.P. 3	—	46	13	1	—	—	—	14	14	2	4
P.P. 4	—	49	11	—	—	—	—	11	9	6	3
P.P. 5	4	25	24	6	1	—	—	31	14	10	20
M.P. 2	9	49	2	—	—	—	—	2	2	15	1
M.P. 3	15	45	—	—	—	—	—	—	—	11	—
M.P. 4	23	37	—	—	—	—	—	—	—	10	—
M.P. 5	57	3	—	—	—	—	—	—	—	—	—
D.P. 1	—	51	7	2	—	—	—	9	8	1	2
D.P. 2	52	8	—	—	—	—	—	—	—	7	—
D.P. 3	47	13	—	—	—	—	—	—	—	10	—
D.P. 4	48	12	—	—	—	—	—	—	—	10	—
D.P. 5	42	18	—	—	—	—	—	—	—	17	—

† Two boys had seven centres and one had eight.

TABLE IV

THE NUMBER OF CENTRES OF OSSIFICATION THAT APPEARED IN THE LEFT FOOT IN SIXTY GIRLS BETWEEN THE AGES OF TWO AND FOUR YEARS

Bone	Number of centres in each girl					Total with multiple centres	Multiple centres showing some fusion	Total with no centre at first. Later	
	None	One	Two	Three	Four			Single	Multiple
M. 1	—	17	33	8	2	43	21	—	20
M. 2	1	46	13	—	—	13	8	11	21
M. 3	1	30	29	—	—	29	9	13	14
M. 4	9	29	16	5	1	22	9	20	10
M. 5	14	32	12	2	—	14	5	29	5
P.P. 1	—	33	9	9	9	27	24	—	20
P.P. 3	—	60	—	—	—	—	—	—	4
P.P. 3	—	60	—	—	—	—	—	—	4
P.P. 4	—	60	—	—	—	—	—	—	3
P.P. 5	—	55	5	—	—	5	5	8	1
M.P. 2	2	58	—	—	—	—	—	7	1
M.P. 3	10	50	—	—	—	—	—	6	—
M.P. 4	28	32	—	—	—	—	—	7	—
M.P. 5	59	1	—	—	—	—	—	—	—
D.P. 1	—	60	—	—	—	—	—	—	—
D.P. 2	21	39	—	—	—	—	—	30	—
D.P. 3	12	48	—	—	—	—	—	39	—
D.P. 4	8	52	—	—	—	—	—	38	—
D.P. 5	28	32	—	—	—	—	—	26	—

radio-opaque changes developing between the original foci or by the outgrowth of strands of osseous tissue from the margins of the foci (Figs. 5 to 8 and 9 to 12). In either case one then observed on the radiograph a thin shadow almost as wide as the proximal end of the shaft and irregular in depth. When this occurred the small rounded nuclei were joined by narrow

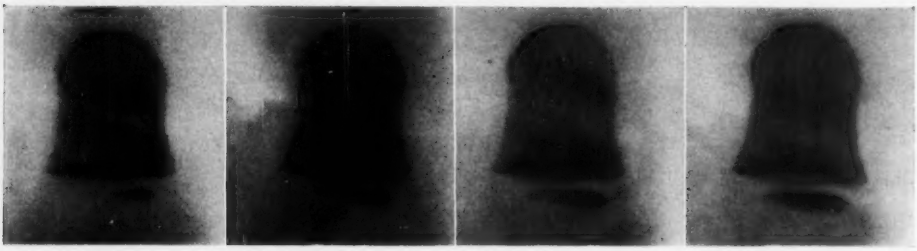

FIG. 5 FIG. 6 FIG. 7 FIG. 8

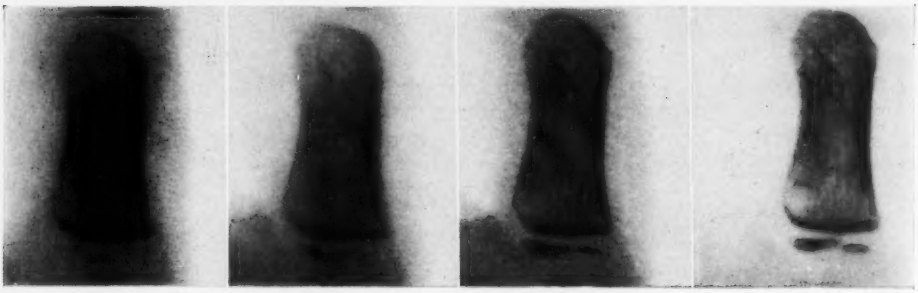

FIG. 9 FIG. 10 FIG. 11 FIG. 12

FIG. 13 FIG. 14 FIG. 15 FIG. 16

The sequence of changes, at three-monthly intervals, in an ossifying epiphysis of the first proximal phalanx of the hand of a boy between the ages of 2 years 9 months and 3 years 6 months is shown in Figures 5 to 8. The same changes in the first proximal phalanx of the hand of a girl between the ages of 3 years 3 months and 4 years is shown in Figures 9 to 12, and Figures 13 to 16 show the changes in the fourth metatarsal of a boy between the ages of 3 years 3 months and 4 years.

opaque bridges and resembled, in silhouette, a string of pearls. Later the silhouette was that of a plate which was indented irregularly on its diaphysial aspect.

The remaining proximal phalanges and the middle phalanges of both the hand and foot have epiphysial areas that are thin rectangles. They may have multiple ossific nuclei within the epiphysial area, but usually there are not more than two. These centres were rounded

when they first appeared but became oval in outline before they fused; the line of fusion was usually close to the mid-line of the shaft.

The distal phalanges of the hand and foot have epiphysial areas that are oval in outline; this oval area is comparatively thick in the case of the first distal phalanx. When the epiphysial areas show multiple ossific nuclei these are small and rapidly fuse to form a single centre.

INCIDENCE OF MULTIPLE FOCI OF OSSIFICATION

In assessing the incidence of multiple as opposed to single centres of ossification the sequence of early events was followed only in those bones in which evidence of ossification was absent at the first examination and a centre or centres were visible subsequently.

In the hands the findings show that ossification has started in the epiphysis for each individual bone in most four-year-old boys and in almost all the girls.

In the boys only the epiphysis for the first proximal phalanx developed multiple centres more often than single ones, but among the girls multiple centres did not appear more often than single ones in any epiphysis.

In the foot the fifth middle and distal phalanges may be suppressed at this age; thus the number of epiphyses available for study is reduced. In boys more than girls the development in the foot lags behind that in the hand, and in consequence the epiphyses for some bones became radio-opaque in only a few of the children during the investigation and this accounts for the small number of observations made on some epiphyses.

Multiple centres were more common than single in the first metatarsal and in the first, second and third proximal phalanges of both boys and girls. Thus, in the boys, multiple centres appeared in twenty-three out of twenty-five epiphyses of the first metatarsal and in twenty out of twenty-one epiphyses of the first proximal phalanx.

This high incidence of multiple centres of ossification in the epiphyses of the first metatarsal and first proximal phalanx suggests that this should be regarded as the normal pattern of ossification.

Fusion—Fusion of multiple foci of ossification was evident in many epiphyses at the fourth year in both sexes, but some epiphyses—especially those of the first metacarpal, first metatarsal and first proximal phalanx—continued to show multiple centres at this age.

Etiological considerations—The factors that might be responsible for the development of multiple centres of ossification, for their frequency distribution within the areas under review, and for individual variations in this regard are unknown. Sawtell (1931) suggested that " the possibility that strain during the early walking period, which coincides with the time of rapid ossification of those centres in which irregularities most frequently occur, might be a factor of considerable importance in explaining the higher incidence of anomalies in the foot than in the hand." This explains neither the appearance of this condition in the hand nor the variation in the individual bones of the foot. Todd (1937) stated that a double centre is seen most often in epiphysial cartilages to which muscle is attached. It is difficult, however, to reconcile this statement with the frequency of the condition in the heads of metatarsals; nor would it account for the numerous foci of ossification in the epiphyses of the first metatarsal and first proximal phalanx.

To exclude the possibility that a deficient intake of calcium might be a factor in the high incidence of multiple centres of ossification in the epiphyses, the children were divided into two groups based upon the adequacy or otherwise of their calcium intake, but no difference was found in the incidence of the condition in the two groups. The condition is not related to the rate of skeletal maturation or to the incidence of minor illness.

The form of the cartilaginous epiphysis appears to bear some relationship to the manner of its ossification. In the first metatarsal and first proximal phalanx of the foot the cartilaginous epiphysis is a thin disc, an arrangement which favours the entry of multiple vessels followed by the development of more than one centre of ossification. Such changes may still occur,

but are likely to be less common, in spherical epiphysial areas associated with the second to the fifth metacarpals and metatarsals.

Clinical considerations—If the normal variations of the development of an epiphysis are not recognised they may be ascribed to pathological changes. Thus Jackson, Hanelin and Albright (1954), discussing the conditions other than multiple epiphysial dysplasia that may produce irregular epiphysial development from multiple centres, failed to mention multiple foci of ossification as a normal variation. Again, according to Köhler and Zimmer (1956), the epiphyses for the first metatarsal and the first proximal phalanx of the foot may be divided, giving the impression that they have originated from two centres. They point out that such appearances used to be interpreted as fractures and were later considered to be similar to Köhler's disease. They, however, preferred to regard it as osteochondrosis dissecans. Francis and Werle (1939) also stated that " in the epiphysis of the first phalanx of the great toe ossification is apt to occur in multiple centers, a condition of no clinical importance but possibly significant as indicating a minor expression of osteochondrosis." Others have stressed the importance of the appreciation of the normal, and Caffey (1956) wrote that " normal irregularities have been mistaken for osteochondrosis, cretinoid dysgenesis, rickets, destructive osteitis and fractures," and again " I am convinced that many, perhaps most, of the so-called cases of infantile and juvenile osteochondrosis or osteochondritis described in the literature are actually examples of unrecognised and wrongly interpreted normal variations."

The findings reported in this paper provide ample confirmation of the wisdom of Caffey's conclusions. In order to avoid confusion and error in the diagnosis of such diseases as fragmentation of the epiphyses, osteochondritis and epiphysitis, one must recognise that multiple centres of ossification occur normally in the epiphyses of the human hand and foot.

DISCUSSION

There are several reasons why there has been such little appreciation of the frequency of multiple ossific nuclei at the onset of ossification in epiphyses of the hand and foot. Firstly, only radiographs taken during the early years of life can show these changes. Secondly, small centres of ossification are unlikely to throw clearly recognisable shadows unless all stages of the radiographic process are carefully performed. Thirdly, since most routine radiographs of children at this age are taken after injury there is little interest taken in the shadows thrown by multiple centres of ossification in an epiphysis. The latter may be very small indeed, and, unless each epiphysial area in the radiograph is examined carefully under ideal conditions, such centres may escape detection. Finally, early studies were dependent on radiological apparatus and techniques that failed to reveal sufficient detail.

Few serial radiographic studies have been based on subjects of known race and age in which attention has also been directed to the nutritional status and health record. In most investigations the radiographic material has been drawn from hospital files. When such investigations are reported only an approximate age of the patient is recorded, and references to the race, dietetic status and health are usually omitted. They may reveal suggestive information, but are unlikely to provide reliable evidence relating to the incidence of any particular change and its relationship to nutritional status and general health. Accurate information relating to the changes observed in the epiphyses during growth can be obtained only from the study of radiographs taken at frequent intervals during the growth of individual children.

We agree with Caffey (1956) who stated: " It is a pity that, 60 years after Roentgen's discovery of X-rays, knowledge of the normal is still so defective—a deficiency which can be overcome only by comprehensive radiologic study of large groups of healthy infants and children of all ages."

SUMMARY AND CONCLUSIONS

1. The occurrence of multiple centres of ossification in the epiphyses of the long bones of the hand and foot is shown to be frequent, and in the first metatarsal and first proximal

phalanx of both hand and foot in both sexes the normal pattern of epiphysial ossification must be regarded as taking place in this way.

2. Multiple centres of ossification are shown to occur simultaneously in several epiphyses of the same hand or foot.

3. There seems to be a relationship between the shape of an epiphysial area and the pattern of ossification occurring within it.

4. Care should be taken to avoid confusing these normal patterns of ossification with radiological appearances caused by pathological changes.

This work was supported financially from Medical Research funds of the University of Melbourne and a grant provided by H. J. Heinz Company Pty. Ltd.

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CHONDROLYSIS IN ARTHRITIS

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Articular cartilage is composed of cells surrounded by a matrix of protein—chondroitin sulphate complex. It is nourished by diffusion from the synovial fluid. It is probable that synovial fluid is a dialysate of plasma, to which another mucopolysaccharide—protein complex containing hyaluronic acid—has been added by synovial cells.

Synovial fluid does not contain fibrinogen (Ropes and Bauer 1953) unless the permeability of adjacent vessels is increased by trauma or inflammation. After these events fibrin clots may be found but they do not persist. What is the mechanism by which fibrin is removed from joint surfaces? Our own studies have shown that whenever there is fibrinogen there is plasminogen in synovial fluid; Astrup (personal communication) has demonstrated the presence of plasminogen activator in synovial tissue, and I have found that cartilage *per se* will also activate plasminogen (Fig. 1). Conditions such as trauma and inflammation that

FIG. 1

A thin slice of human articular cartilage has been laid on freshly clotted human fibrin and incubated at 37 degrees overnight. The cartilage has activated the plasminogen contained in the fibrin, with consequent fibrinolysis.

release thromboplastin, leading to the clotting of fibrinogen, may also be expected to ensure the digestion of the fibrin clot so formed. The exceptions to this generalisation are mentioned later.

Synovial fluid normally contains inhibitor to plasmin but nevertheless the fibrin is digested. Plasmin, formed by the activation of plasminogen by tissue activator, adsorbs on to fibrin and digests it; no free plasmin remains as it is then inactivated by inhibitor in the surrounding fluid. There may well be several inhibitors of plasmin in synovial fluid, and the rate of fibrinolysis is determined by the relative amounts of inhibitor and plasmin.

SUPPURATIVE ARTHRITIS

Let us consider what happens in suppurative arthritis caused by staphylococcus pyogenes or a haemolytic streptococcus. Infections by these organisms usually produce rapid and extensive chondrolysis, more so than in other types of infection. Suppuration *per se* will increase local proteolytic activity—pus cells release proteases, increased capillary permeability and local tissue destruction may eventually raise the plasmin level—but these factors alone are not sufficient to account for the speed with which cartilage matrix is destroyed in streptococcal

FIG. 2

Equal sized portions of bovine articular cartilage were incubated in buffered solutions of bovine plasmin and trypsin and are shown here in comparison with cartilage in buffered saline alone.

or staphylococcal infections. Both these organisms produce kinases which activate plasminogen, and plasmin will digest the protein moiety of the mucoprotein of cartilage (Lack and Rogers 1958) (Fig. 2).

Phemister (1924) reported an experiment which led him to the conclusion that chondrolysis in pyogenic arthritis was caused by the digestive action of proteolytic ferments derived very largely from polymorphonuclear leucocytes. He showed that when equal sized pieces of cartilage were placed respectively in saline, tuberculous pus, staphylococcal suspension and staphylococcal pus, only the last digested the cartilage completely within forty hours. Had he put cartilage into a suspension of disrupted leucocytes alone, he would not have observed this rapid destruction. It is evident from experiments carried out in this department that leucoprotease is not itself an important agent in chondrolysis. Keefer, Holmes and Myers (1935) found that leucocytic autolysates from staphylococcal pus digested cartilage and coagulated blood serum. " Digestion of the cartilage was not observed in seven samples of synovial fluid from gonococcal arthritis or in three samples from tuberculous arthritis. In the two cases of staphylococcal arthritis, in which there were large numbers of polymorphonuclear leucocytes, digestion was apparent." The fact that their leucocytic autolysates digested

fibrin suggests the presence of staphylokinase or plasmin, but nothing was known of the plasmin system when they made their experiments. Further evidence that they were dealing with the action of plasmin is provided in their other paper (Holmes, Keefer and Myers 1935), in which they reported that some synovial fluids became proteolytic and chondrolytic after removal of antitryptic substances with chloroform.

Thomas and others (Thomas 1956; Spicer and Bryant 1957; Spicer and Bryant 1958; McCluskey and Thomas 1958; Bryant, Leder and Stetten 1958) have shown that when rabbits are injected intravenously with crude papain the ear cartilages of the living animals soften in a few hours, but that they return to normal in three or four days. The proteolytic attack of the papain has been shown to be on the cartilage matrix; as the cartilage cells have not been affected, it must be presumed that these cells in the rabbit are capable of restoring the matrix in two days. Restoration of matrix presumably depends on the number and metabolic activity of the cartilage cells, which may be related to the age of the subject. It would be difficult to achieve such a high concentration of active plasmin in cartilage by intravenous injection because there is such excess of plasmin inhibitor in rabbits and in man. But the papain experiments may provide useful models.

Pathogenic streptococci and staphylococci produce toxins that kill cartilage cells. It is probable, therefore, that in continuing infections by these organisms not only is matrix removed but regeneration is impaired or prevented in proportion to their toxic action on cartilage cells.

The chondrolytic activity in arthritis caused by other pyogenic organisms such as the gonococcus and meningococcus is considered to be less severe because they do not produce activators of plasminogen, and such activity as occurs is caused by tissue activation. Disrupted leucocytes will activate plasminogen, but more slowly than bacterial kinases.

TUBERCULOUS ARTHRITIS

In tuberculous arthritis there is no direct attack on cartilage. Instead there is the sequence of fibrin deposition, fibroblastic outgrowth with pannus formation over the surface of cartilage, and subchondral granulation tissue undermining the cartilage below. " The hyaline articular cartilages display no vital reaction on their own account. Even though they may be detached or slowly eroded by granulation tissue, the joint cartilages persist for a long time in a tuberculous joint. They are not attacked by proteolytic enzymes, as is the case in a suppurative arthritis." (Collins 1949). Tuberculous tissue has a high content of plasmin inhibitor. Tuberculosis of the synovium inhibits the normal fibrinolytic mechanism so that fibrin accumulates and persists on joint surfaces. Fibroblasts may subsequently grow into this fibrin, leading to pannus formation or to fibrous ankylosis. Cartilage degeneration occurs as a result of the interference with nutrition and not as a consequence of toxic or proteolytic attack.

When a tuberculous joint is secondarily infected with a staphylococcus there may be bony union instead of fibrous ankylosis because the staphylococcus is able to remove intervening cartilage in the way described. Bony ankylosis may occur in tuberculous arthritis but is much slower.

RHEUMATOID ARTHRITIS

Pannus formation is even more conspicuous in rheumatoid arthritis, and, if one accepts the view that fibroblastic proliferation over cartilage surfaces follows fibrin deposition, one is thrown back to the question: Is there any reason for supposing that persistence of fibrin characterises the rheumatoid state? As the physiological clearing mechanism for removing fibrin appears to be plasmin, is there any evidence that plasmin activity is retarded in rheumatoid arthritis? Thomas and Dingle (1955) found serum anti-plasmin levels increased and serum plasmin levels reduced in rheumatoid arthritis. A study of plasmin inhibitor and

activator in synovial membrane and fluid from patients with rheumatoid arthritis is about to be started in this hospital. An abnormally high inhibitor level in tissue fluids may help to explain the failure to remove protein in other situations in this disease.

DEGENERATIVE ARTHRITIS

Cartilage matrix is lost in degenerative arthritis. It is possible that in a large proportion of instances this is a failure of replacement of ordinary wear and tear. Repeated trauma might release sufficient activator from synovial tissue or cartilage to bring about a digestion of the cartilage surface by plasmin, but there is no experimental evidence for this.

It has been pointed out that plasmin attacks the protein of cartilage, releasing the chondroitin sulphate. Chrisman *et al* (1958) reported raised sulphate levels in the synovial fluid in established degenerative arthritis and lowered levels in rheumatoid arthritis. It is interesting that they should also find a profound lowering in both varieties of arthritis after treatment with intra-articular hydrocortisone, as this drug has been reported to have an inhibitory effect on plasmin activity.

SUMMARY

Plasmin, a proteolytic enzyme derived from the blood, may be activated in synovial fluid both by trauma to synovial tissue and cartilage, and by kinases produced by streptococci and staphylococci. Plasmin normally removes fibrin, but, when in excess, attacks the protein of cartilage matrix. Conversely, excess inhibitor favours the persistence of fibrin and subsequent fibrosis. The relationship of excess protease to the chondrolysis of suppurative arthritis and of excess inhibitor to pannus formation and fibrous ankylosis in tuberculous and rheumatoid arthritis are discussed.

This research has been aided by a grant from the Research Fund of the University of London. I wish to acknowledge the gift of bovine plasmin from Messrs Parke Davis and Company, Detroit; and Fraction III of human plasma from E. R. Squibb and Sons, by courtesy of the American National Red Cross.

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ON THE VISCOSITY AND pH OF SYNOVIAL FLUID AND THE pH OF BLOOD

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During the last ten years there have been many studies of the physical and chemical properties of synovial fluid in relation to the production and prevention of joint lesions. These researches on the properties of normal human synovial fluid have nearly all been done on specimens obtained *post mortem*, all other work on the normal having been done on fluid obtained from the joints of cattle. Furthermore, there appears to have been no investigation into the changes, if any, in normal human synovial fluid with age or with variations in pH, which by affecting the viscosity may have an important effect on the lubrication and nutrition of the joint surfaces. To elucidate these problems we studied: 1) the viscosity of synovial fluid from normal human knee joints at different ages; 2) viscosity changes in traumatic and osteoarthritic knee joints; 3) the relationship between the pH of blood and synovial fluid in normal, injured and osteoarthritic knee joints; and 4) the pH of synovial fluid at different ages.

MATERIAL

Samples of blood and synovial fluid were collected from patients attending the orthopaedic department of the Battersea General Hospital over a period of approximately five years. Samples were taken from patients with normal, injured and arthritic knee joints, as shown in Table I.

TABLE I

MATERIAL FOR STUDY

		Males	Females	Total	Age range (*years*)
Normal	synovial fluid	39	52	91	8–80
	blood	20	38	58	8–78
Traumatic	synovial fluid	51	12	63	7–68
	blood	50	10	60	7–68
Osteoarthritic	synovial fluid	11	34	45	30–74
	blood	4	17	21	47–74

Examination and aspiration of knee joints—All patients from whose knees synovial fluid was taken were examined clinically and radiographically. A knee joint was accepted as normal if it had not been injured, gave rise to no complaints and seemed normal on clinical examination. Fluid withdrawn from normal knee joints was taken, with permission, from patients under general anaesthesia for operations not related to the knee.

The joint fluid was aspirated by a " Vim " all-glass 20-millilitre autoclaved syringe fitted with a No. 1 S.G. 2½-inch long Record needle. The fluid was expelled into small sterilised vials and immediately closed with sterile rubber bungs to exclude air. The vials used were of two sizes: a vial of 3 to 4 millilitres capacity for blood and such samples of synovial fluid of which ample quantities

were available; and a small vial made from the rounded end of a test tube with a capacity of approximately 1 millilitre, which, by the insertion of smaller rubber bungs, could be reduced to 0·3 millilitre. The bungs were pushed down on the fluids in such a way as to exclude air bubbles. Between collecting and testing, the fluids were kept in a refrigerator at zero temperature, which, it is agreed with other workers, causes no change in viscosity even after several weeks (Fessler, Ogston and Stanier 1954).

The blood samples were of venous blood taken from the arm at the same time that synovial fluid was aspirated, with only momentary manual occlusion of the veins. The blood samples were collected and stored under the same conditions as the synovial fluid.

VISCOSITY MEASUREMENTS

Viscometer—All viscosity measurements were made with the same glass capillary viscometer (Fig. 1) specially designed for working with small volumes (sometimes less than 0·5 millilitre) obtainable from normal knee joints.

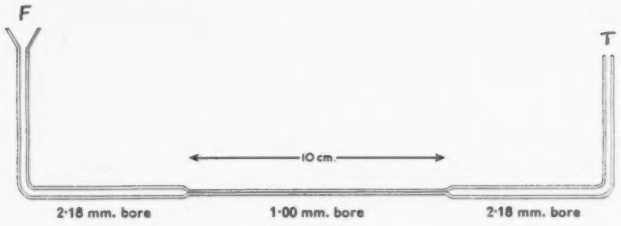

FIG. 1
Capillary viscometer.

Determination of viscosity—Synovial fluid is not a simple Newtonian fluid; its viscosity, measured for example by a capillary tube method and calculated by Poiseuille's formula, decreases very markedly with increasing flow rate. Poiseuille's formula is strictly not applicable to such liquids, since even at constant flow rate the rate of shear or velocity gradient increases from zero along the axis of the tube to a maximum at the periphery, and therefore the viscosity will have different values in the different annular layers of the liquid. Thus the viscosity calculated by the formula is only an apparent viscosity, serviceable however for comparisons. *Method*—The capillary tube of the viscometer was immersed horizontally in a water bath maintained at 38 ± 1 degree centigrade. The experiment consisted in timing the flow of a constant volume of synovial fluid through the capillary tube under different constant pressures. By means of a tap at the end marked T, the tube could be connected either to a filter pump or to a large reservoir of air, or it could be shut off from both. The pressure in the air reservoir could be raised to a maximum of about 100 centimetres water above atmospheric; the pressure difference P centimetres water across the tube (the other end being open to the atmosphere) was measured with a water monometer. The reservoir was large enough for there to be no perceptible change in pressure caused by the slight change in volume as the fluid moved along the tube. The range of pressures used corresponded to a stress* range of from 2·5 to 250 dynes/centimetres^2.

Sufficient synovial fluid (about 0·33 millilitre) was poured from the vial in which it had been collected and stored to fill the funnel F; it was then drawn down to fill the capillary tube and about 7 centimetres of the wider tube. Consistent values for the time of flow of a volume which occupied 5 centimetres of the wider tube were obtained and could be repeated even after the fluid had been subjected to other pressures, which were chosen so that the time of flow was not less than ten seconds.

* Stress $= \frac{Pgr}{2l}$ dynes/centimetres^2 where $g = 981$ cm. sec^{-2}, r = radius, l = length of capillary tube.

The viscous anomaly—The apparent viscosity of a fluid is proportional to the product Pt where P centimetres water is the pressure difference across the tube and t seconds is the time of flow. The product Pt was plotted against t on logarithmic two-way scales for each fluid. A few typical plots are shown in Figure 2, together with that for 95 per cent glycerine. Since the viscosity of glycerine is independent of flow rate, the glycerine plot is a straight line parallel to the time axis. The synovial fluid plots are straight lines of positive slope, indicating the increase of viscosity with time of flow. The equation of such a line may be written

$$\log Pt = k \log t + \log C$$

where k is the gradient of the line and C another constant. k is a measure of the viscous anomaly of the fluid; it is the logarithm of the ratio of the viscosities for a tenfold increase in flow time (which for a Newtonian fluid would be a tenfold decrease in the average velocity gradient* in the tube). The anomaly has been defined differently by Ogston and Stanier (1953), and Johnston (1955), as the ratio of the viscosities at two chosen velocity gradients, and by Sundblad (1953) as the logarithm of the ratio of the viscosities at two chosen pressure gradients.

Comparison of fluid viscosities—Because the viscosity of a snyovial fluid increases with time of flow, the fluids can be compared only at the same time of flow. For this purpose a flow time of 100 seconds was chosen because it lay within the measured times of nearly all the fluids. The pressures P_{100} for a time of flow of 100 seconds are proportional to the viscosities at this flow rate and are used to compare them. They can easily be read off the graphs of Figure 2 because the numbers on the ordinate scale represent $Pt \times 10^{-2}$ and therefore, for $t = 100$ only, also represent P_{100}. The viscosity can be obtained in C.G.S. units (poise) from the value of $P_{100} = 11{\cdot}3$ for 95 per cent glycerine, which at 38 degrees centigrade has a viscosity of 1·6 poise. Thus viscosity in poise $= 1{\cdot}6\ P_{100}/11{\cdot}3 = 0{\cdot}14\ P_{100}$. A time of flow of 100 seconds would represent for a Newtonian fluid a velocity gradient of 12·7 seconds^{-1} in our tube.

Correlation of viscosity of normal synovial fluid with age—The viscosities of all normal fluids (measured at a flow time of 100 seconds) are plotted against age of the donor in Figure 3. Although there is a considerable range of viscosities at any particular age, there is a clear downward trend of viscosities with age. Panizza (1930) found a decrease of viscosity with age in cattle, but Davies (1944) was unable to confirm this. Working on normal human synovial fluid, we found the highest viscosity to be nearly 14 poise for a boy of fifteen and the lowest 0·6 for a woman of eighty. The equation of the regression line of viscosity on age was calculated by the method of least squares and is:

$$P_{100} = 88 - 0{\cdot}8\ A$$
$$\text{or } \eta = 12{\cdot}6 - 0{\cdot}11\ A$$

where A = age in years and η = viscosity in poise. This line is shown in Figure 3. The coefficient of correlation is 0·71.

Viscosity of synovial fluid from injured joints—The effect of trauma on the viscosity is shown by plotting the viscosity of the fluids from injured joints against age and drawing on the same graph the regression line for the viscosity of normal fluids (Fig. 4). With the exception of four which will be referred to later, all the traumatic fluids had a viscosity less than 1 poise irrespective of age; the points lie far below the regression line (which indicates a viscosity of 4·4 poise even at seventy years of age). The reduction in viscosity is therefore very much greater for young people than for old. The variations at a given age are determined chiefly by the degree of trauma and the gradual restoration to normal; the correlation with age disappears. The average viscosity of the whole group is $0{\cdot}8 \pm 0{\cdot}2$ poise, but, excluding the four with much higher values, the average is $0{\cdot}31 \pm 0{\cdot}04$.

* Average velocity gradient $= 8V/3\pi r^3 t$ where r = radius of capillary tube and V/t = volume of liquid flowing through it per second. Johnston (1955) gives some experimental evidence that the effective velocity gradient in synovial fluid is also inversely proportional to the time of flow.

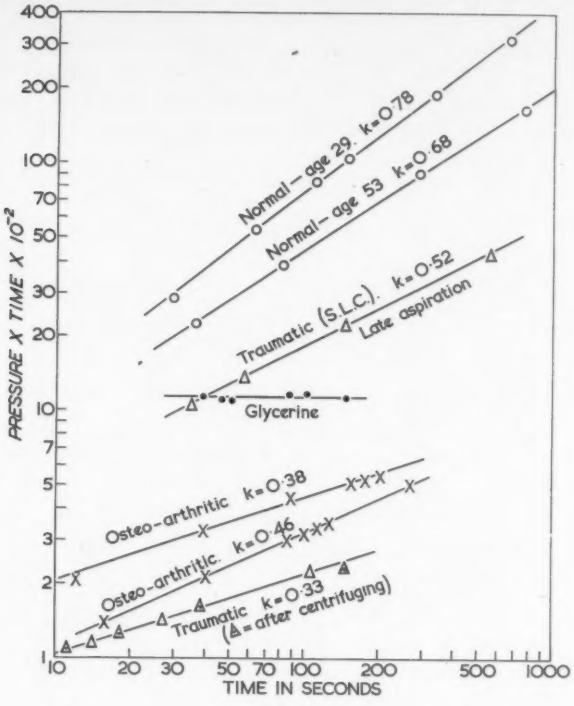

FIG. 2
Increase of viscosity of synovial fluids with time of flow.

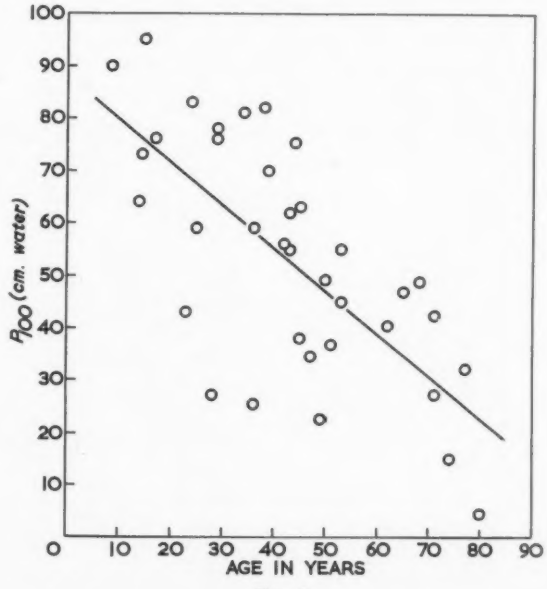

FIG. 3
Decrease of viscosity of normal fluid with age.

Viscosity of synovial fluid from osteoarthritic joints—The effect of osteoarthritis on viscosity is shown similarly in Figure 5. Again, all the viscosities are below the regression line, the majority reduced to a value less than 1 poise. There are, of course, no values for very young people, the youngest osteoarthritic patient being thirty-eight years old. The four fluids with viscosities only a little below the regression line were all from patients suffering from mild

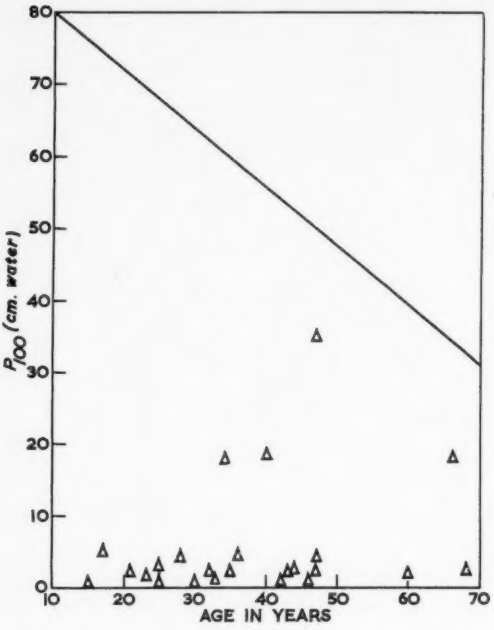

FIG. 4

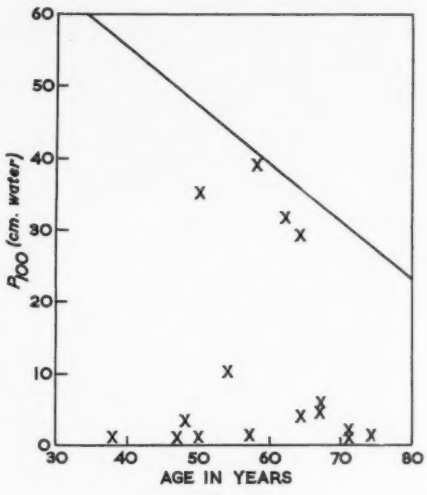

FIG. 5

Figure 4—Viscosity of fluids from injured joints, and the regression line for normal fluid. Figure 5—Viscosity of fluids from osteoarthritic joints and the regression line for normal fluid.

osteoarthritis. The degree of osteoarthritis influences the range of viscosity values present at a particular age and destroys the correlation with age. The average viscosity is $1{\cdot}5 \pm 0{\cdot}5$ poise, excluding the four mild cases $0{\cdot}4 \pm 0{\cdot}1$.

The viscous anomaly in the three types of fluid—The viscous anomaly is measured by the slopes of the lines of Figure 2: it can be seen that for those fluids with high viscosity the lines are steeper than for low viscosity fluids. If the logarithm of the viscosity at the same flow rate for all fluids (or log P_{100}) is plotted against the viscous anomaly, a linear correlation is apparent (Fig. 6). The equation of the line, calculated by the method of least squares is:

$$\log. P_{100} = 3{\cdot}43k - 0{\cdot}79$$

The coefficient of correlation is 0·96.

If the regression lines are calculated separately for the three different types of fluid the resulting equations are not significantly different from the above or from each other.

DISCUSSION

The viscosity of synovial fluid depends almost entirely on the presence in it of hyaluronic acid (Cajori and Pemberton 1928, Sundblad 1953, Ropes and Bauer 1953). There are two factors which determine the viscosity of any particular synovial fluid: 1) the concentration of hyaluronic acid in the fluid; and 2) the state of polymerisation of the hyaluronic acid molecule.

Careful consideration of our results does not, unfortunately, allow us to come to any conclusion on the question of which of these two factors is concerned in the decrease of viscosity which we have found to occur in the normal synovial fluid with age and associated with the pathology present in our other two groups of specimens. In view of our findings it may, nevertheless, be useful to comment on the probable factors acting in each group.

The work of Halliburton (1888) on the estimation of mucin in skin shows that the mucin content decreases markedly as age increases. We think that it is possible, indeed probable, that a decrease of mucin in so widely distributed a tissue as skin indicates a decrease of this substance throughout the body. It would therefore be expected that the mucin in synovial fluid would decrease with advancing years, thus accounting for the decrease of viscosity which we found with age.

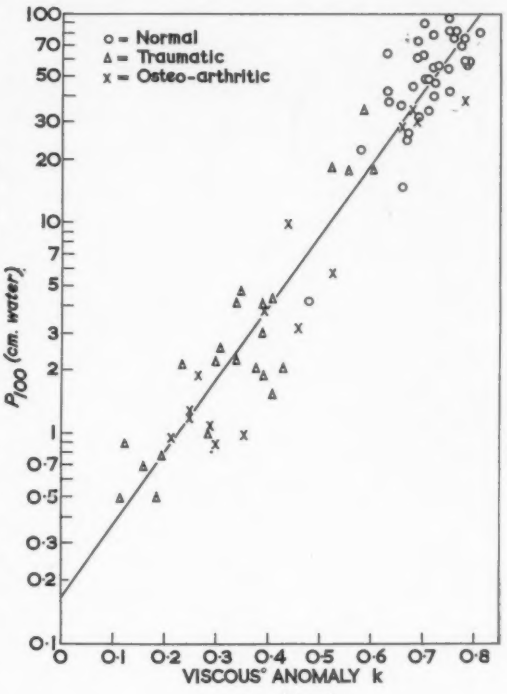

FIG. 6
Correlation between viscous anomaly and logarithm of viscosity.

All the examples of fluid aspirated from injured joints (except for four taken some time after the injury) show a dramatic fall in viscosity as compared with the normal at the same age. As transudation from blood vessels into tissue spaces takes place in response to injury, and as the synovial cavity is now generally regarded as a large tissue space, increase of synovial fluid after injury is to be expected. Unless a sudden large production of hyaluronic acid occurs at the same time, and there is no evidence that this is so, the transudate will act as a diluent causing a decrease in the concentration of mucin in the synovial fluid and a consequent fall in its viscosity. The severity of the injury determines the size of the effusion and hence also the concentration of mucin and the relative viscosity. This is borne out by Sundblad's work (1953) in which he showed that the concentration of hyaluronic acid in traumatic arthritis varies approximately in inverse proportion to the fluid volume.

The four cases in this series which did not show marked decrease in viscosity were specially investigated. We found that in each case there had been an interval varying from seventeen days to several months between the original injury and the operation at which the fluid was collected. All four examples were of semilunar cartilage injury. In one of these, fluid had also been aspirated immediately after the injury to the cartilage and the viscosity was then 0·3 poise. At operation on the same knee four months later another specimen was obtained; this had a viscosity of 5 poise, which, although lower than the value of 7 poise given by the regression line at the patient's age, is still within the normal range.

Our series of fluids from injured joints consists of twenty-four specimens of which fifteen were from patients with cartilage injuries and nine from patients with acute sprains of the knee. Sundblad (1953) divided his traumatic fluids into three groups. His group (1*a*) corresponded to our traumatic group, excluding cartilage injuries; his group (2) consisted of

fifteen cartilage injuries and was therefore comparable with our cartilage cases; his group (1*b*) is not represented in our series and is therefore excluded from comparison (Table II).

TABLE II

RELATIVE VISCOSITIES ($\eta_{rel.}$)

Fluid group	Sundblad		Present authors	
	Number in group	$\eta_{rel.}$	Number in group	$\eta_{rel.}$ (*at a time of flow of* 100 *seconds*)
Normal	2	>300	36	80–1900
Traumatic, excluding lesions of cartilages	20	3–59	9	10–80
Lesions of cartilages:				
(*a*) Aspirated within one week of injury	15	3–300	11	20–100
(*b*) Aspirated some weeks after injury.			4	360–700
Degenerative arthritis:				
(*a*) Severe	42	3–94	12	20–200
(*b*) Mild			4	600–800

Except for the four cases referred to above all our fluids from patients with cartilage injuries were aspirated within a week of the injury and show viscosities comparable with those of the nine acute traumatic fluids which were taken within a few days of the injury. All our twenty traumatic cases therefore fall into the same group as Sundblad's group (1*a*) and show a similar range of viscosities. We suggest that the difference in the relative viscosities between Sundblad's groups (1*a*) and (2) may be due to the interval between the injury and the collection of the fluid, and not to any difference in the particular tissue injured, i.e., ligaments and synovial membrane or fibrocartilage. One would expect a gradual restoration of the joint to normal after injury to be accompanied by a rise in the viscosity of the synovial fluid to the level appropriate to the age of the subject, and this in fact appears to take place.

Our series of fluids from osteoarthritic joints consists of sixteen specimens, all of which showed a decrease in the viscosity as compared with the normal for the age of the subject. In this our findings are in agreement with those of Sundblad (1953), Ropes and Bauer (1953) and others. Again we are unable to say whether the decrease in the viscosity is due to a change in the concentration or the state of polymerisation of the mucin. In a few cases a small effusion, demonstrated by the patellar tap, was present; and in all cases the aspiration of the fluid was effected with far greater ease than in the case of the normal joint. This indicates the presence of a greater volume of fluid in these joints and suggests the probability of some dilution, but it in no way excludes depolymerisation.

The degree of polymerisation of the hyaluronic acid—Blix and Snellman (1945), Sundblad (1953, 1954) and Bollett (1956) have measured the intrinsic viscosity* of synovial fluid hyaluronic acid in order to investigate its degree of polymerisation. The results of Sundblad and of Bollett are reproduced in Table III.

Sundblad found the mean intrinsic viscosity of normal fluids and of group (1*a*) traumatic fluids to be about 39, whereas in traumatic arthritis caused by lesions of the cartilages and in osteoarthritis it was reduced to about 30. He concluded from this that the hyaluronic acid is of the same degree of polymerisation in group (1*a*) as in normal fluid, but is degraded in

* Intrinsic viscosity=limiting value of η_{sp}/C when the concentration $C \rightarrow 0$. $\eta_{sp}=\eta_{rel.}-1$. See Bull (1951) and Lauffer (1942).

TABLE III

MEAN VALUES AND STANDARD ERRORS OF INTRINSIC VISCOSITIES AND ANOMALIES

Fluid group	Sundblad		Bollet		Present authors		
	Number in group	Intrinsic viscosity	Number in group	Intrinsic viscosity	Number in group	Reduced anomaly	Anomaly k
Normal . .	2	39·3	9	69·3±4·2	36	—	0·71±·01
1*a* Traumatic . .	20	39·1±1·1	6	32·5±1·7	5	0·048±·008	0·21±·035
2 Lesions of the cartilage	15	30·1±1·8			7	0·075±·009	0·34±·02
3 Osteoarthritic . .	42	29·8±1·4	3	49·8±5·8	7	0·053±·008	0·28±·02

groups (2) and (3). His comparison with normal fluids is unconvincing because it is based on only two samples, which cannot be considered representative of the wide range of fluid viscosities from subjects of all ages. Bollett's mean value of 69 for nine normal fluids is significantly higher than Sundblad's and also higher than his own mean value of 32·5 for six traumatic fluids. Of these six the highest individual value was 38, and the lowest of Bollett's values for normal fluids was 54. There is thus no indication here that some traumatic fluids are undegraded, though it is possible that all these six fluids were from knees with cartilage injuries.

In view of this contradiction, and although we have made no direct determination of intrinsic viscosity, we have investigated a property which has been shown by Sundblad (1954) to have a positive correlation with the intrinsic viscosity, and called by him "anomalous viscosity." Since, however, it is a measure of the anomaly and is not a viscosity, we have called it the "reduced" anomaly, to distinguish it from the anomaly k measured by the slopes of the lines of Figure 2. It has the advantage over intrinsic viscosity that no determination of the concentration is necessary for its evaluation, which is therefore a simpler and more practical clinical method of estimating the degree of polymerisation, and was used by Sundblad (1954) for this purpose during treatment of rheumatoid arthritis with hydrocortisone. It is measured by him as the logarithm of the ratio of the intrinsic viscosities at stresses of 7 and 17 dynes/centimetres^2 respectively. At low concentrations the intrinsic viscosity $[\eta]$ can be expressed as

$$[\eta]=\frac{\eta_{sp}/C}{1+0{\cdot}16\eta_{sp}}$$

where η_{sp} is the specific viscosity and C is the concentration of the hyaluronic acid. This holds for values of η_{sp} up to 20. When the ratio of the intrinsic viscosities for the same fluid at two different stresses is taken, the common factor C disappears. We have therefore been able to calculate the reduced anomaly for those few of our fluids for which $\eta_{sp}<20$ at a stress of 7 dynes/centimetres^2. For those fluids with η_{sp} between 20 and 50, we have used another approximate formula given by Sundblad:

$$[\eta]=\frac{\eta_{sp}/C}{2+0{\cdot}11\eta_{sp}}$$

The results of this investigation are also given in Table III, together with the anomaly k.

If the reduced anomaly is a reliable indication of the intrinsic viscosity then our results also do not confirm Sundblad's, since we find the reduced anomaly least for group (1*a*) traumatic fluids and higher (at the 5 per cent level of significance) in cartilage injuries, with an intermediate value in osteoarthritis. Unfortunately, since the reduced anomaly can be found only for fluids of low specific viscosity, it could not be calculated for any normal fluids,

but the anomaly k shown in the last column of Table III runs parallel to the reduced anomaly and is much the highest for normal fluids, as well as being fairly constant (standard deviation 0·06 or 8½ per cent of the mean). It is tempting to attribute this high value to the high state of polymerisation in normal fluids indicated by Bollet's figure for their mean intrinsic viscosity.

Finally we would like to discuss the value of viscosity measurements. It is now generally accepted that the function of synovial fluid is twofold, namely as a nutrient fluid for joint cartilage and as a lubricant to enable movement to take place between the cartilaginous

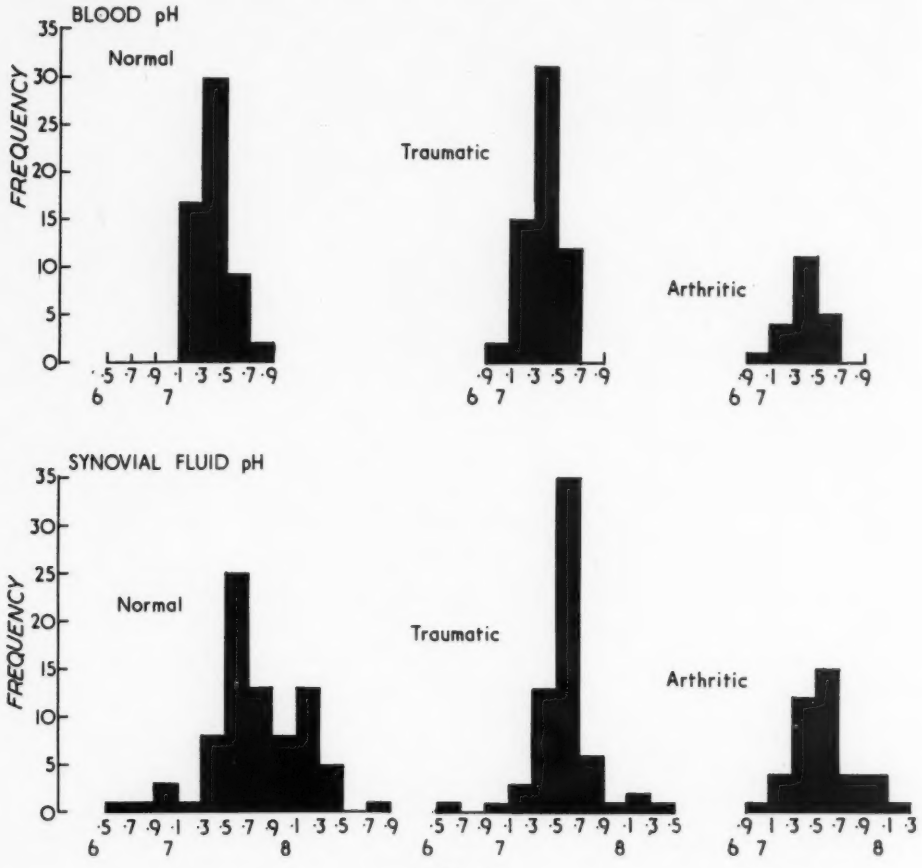

FIG. 7

Histograms showing pH of blood and of synovial fluid in the normal state, in cases of joint injury, and in osteoarthritis.

surfaces. As far as we are aware no work has been done on the effect of a change of viscosity on the nutritional function of synovial fluid, but Barnett (1956) has shown that its efficiency as a lubricant is undoubtedly affected. Davies (1944) pointed out that for fluid lubrication the viscosity of the lubricant should vary directly as the load and inversely as the velocity. An increase of body weight is common with age and the velocity of joint movement generally decreases, hence a decreased viscosity would be detrimental to the functional efficiency of the joint and may therefore precipitate the onset of osteoarthritic changes.

pH MEASUREMENTS

pH meter—The pH meter used was a Marconi T.F. 5117 with serum electrode T.F. 708A.

pH estimations were made on 139 samples of blood and 183 samples of synovial fluid. Both blood and synovial fluids were classified as normal, traumatic or osteoarthritic; a blood sample was included in a pathological group if one or both knees were not normal.

Blood pH—The blood pH numbers in the three classes, normal, traumatic and osteoarthritic, were arranged in groups with a range of 0·2 and frequency histograms constructed (Fig. 7).

TABLE IV

BLOOD pH

Class	Number in class	Mean pH and standard error
Normal .	58	7·382±0·020
Traumatic .	60	7·382±0·020
Osteoarthritic	21	7·380±0·029
All classes	139	7·381±0·013

TABLE V

SYNOVIAL FLUID pH

Class	Number in class	Mean pH and standard error
Normal .	79	7·768±0·044
Traumatic .	63	7·559±0·031
Osteoarthritic	41	7·549±0·040

TABLE VI

SIGNIFICANCE OF DIFFERENCE OF MEANS (FISHER 1954)

Classes		Difference of means	Probability of chance occurrence = P
Synovial fluid.	Normal-traumatic .	0·209	<0·001
	Normal-osteoarthritic .	0·219	<0·002
	Traumatic-osteoarthritic	0·010	>0·8
Normal synovial fluid—blood . .		0·387	<0·001
Traumatic synovial fluid—blood. .		0·177	<0·001
Osteoarthritic synovial fluid—blood .		0·169	0·01

The peak frequency in each class was found to occur at the same range group 7·30 to 7·49. Table IV shows the mean pH in each class with its standard error. The differences between the classes are insignificant, being much less than the standard errors. The mean of all the classes taken together, 7·38±0·01, is about 0·02 less than the lower value quoted by Sunderman and Boerner (1949), which difference may be explained by the fact that nearly all our samples were taken under anaesthesia.

Synovial fluid pH—The synovial fluid pH numbers were grouped in the same way and the frequency histograms (Fig. 7) show that: 1) the peak frequency occurs at the range group 7·50–7·69 in all the three classes, which is one range higher than that of the peak frequency for all three classes of blood. 2) There is a wider range of pH, 6·5 to 8·9, than for blood, 6·9 to 7·9. 3) The second peak in the normal class at the range group 8·10–8·29 is responsible for a significant difference between the mean pH of the normal fluid and that of either the traumatic or the osteoarthritic. Table V shows the mean pH of each class with its standard error, and Table VI shows the difference between the class means taken in pairs. There is no significant difference between the two pathological synovial fluids. 4) The differences between synovial fluid pH in each class and mean blood pH are also given in Table VI. They are all highly significant.

Changes of synovial fluid pH with age—The pH measurements in each class were regrouped according to the age of the patient. The mean pH in seven age groups is shown in Table VII. The normal fluid of the under twenties had a mean pH of 8·1, significantly higher than that

TABLE VII

pH NUMBERS IN AGE GROUPS

Class	Age group	1	2	3	4	5	6	7
	Included ages (*years*)	7–19	20–29	30–39	40–49	50–59	60–69	70–78
Normal	Number in group	12	15	10	22	10	5	5
	Mean pH	8·10	7·65	7·77	7·76	7·65	7·63	7·75
	Standard error	0·13	0·09	0·16	0·08	0·05	0·15	0·08
Traumatic	Number in group	12	11	13	16	5	6	0
	Mean pH	7·53	7·40	7·59	7·69	7·51	7·52	—
	Standard error	0·03	0·06	0·03	0·10	0·05	0·03	—
Osteoarthritic	Number in group	0	0	1	2	15	17	6
	Mean pH	—	—	7·60	7·34	7·54	7·60	7·49
	Standard error	—	—	—	0·17	0·08	0·05	0·09

of normal group 2 ($P<0·01$) or normal group 4. The significance of the difference between group 1 and the other four normal groups is less because the numbers in these groups are smaller. Individual pH values >8 did occur in groups 2, 3, 4 and 6, though the mean values for these groups were below 8 and close to the mean of all the normal values. The mean for group 7 was as high as that in groups 3 and 4. Hence we could find no continuing downward trend of pH with age, only a significantly high value in adolescents.

In every age group the mean pH of normal fluid is higher than that of either pathological fluid, but only significantly so in group 1.

CONCLUSIONS

Viscosity measurements—The viscosity of human synovial fluid taken from ninety-one normal, sixty-three injured and forty-five osteoarthritic knees has been investigated with one and the same capillary viscometer (Fig. 1). The products of pressure difference across the tube (P centimetres water) and time of flow (t seconds) are plotted against time of flow on logarithmic two-way scales for each fluid (Fig. 2). The plots are straight lines of positive slope and the slope is taken as a measure of the fluid's viscous anomaly (k).

The viscosities of the fluids are compared by comparing the pressures P_{100} at the same time of flow of $t=100$ seconds (which for a Newtonian fluid would correspond to an average velocity gradient of 12·7 seconds^{-1}). A downward trend of the viscosity of normal fluid with age is demonstrated (Fig. 3), indicating that the viscosity at the age of sixty is likely to be approximately half that at the age of ten. No correlation with age was demonstrable in pathological fluids, the average viscosity of which is less than one-tenth that indicated for normal fluid at seventy years of age.

A positive linear correlation, which includes all the normal and pathological fluids, is shown between log P_{100} and the viscous anomaly k (Fig. 6). The normal fluids, which have the highest viscosities, have also the greatest anomalies, but the same relationship exists for all three types of fluid.

An attempt is made to discover an indication of possible depolymerisation of the hyaluronic acid, though the experimental determination of the relationship between viscosity and concentration, necessary for determining intrinsic viscosity, was not undertaken; instead, a "reduced anomaly" is determined for some of the pathological fluids, since Sundblad (1954) has shown that this quantity has a positive correlation with intrinsic viscosity. It was not possible to make the calculation for normal fluids. The reduced anomaly, like the anomaly k, proves to be least for traumatic fluids, and thus gives no confirmation of Sundblad's finding of high intrinsic viscosity and therefore high polymerisation in traumatic fluids.

pH measurements—One hundred and eighty-three pH measurements have been made on the synovial fluid and 139 on the venous blood of the same patients, grouped according to the knee joint as normal (both knees), traumatic, or osteoarthritic. The mean value for blood pH is $7{\cdot}38\pm0{\cdot}01$, with no significant difference between the groups.

The mean pH of normal synovial fluid is significantly higher ($7{\cdot}77\pm0{\cdot}04$) than blood pH. It is also higher than the synovial fluid pH of both the traumatic group ($7{\cdot}56\pm0{\cdot}03$) and the osteoarthritic group ($7{\cdot}55\pm0{\cdot}04$). These last two are still significantly higher than blood pH.

The distribution of pH within the groups is shown by histograms (Fig. 7).

The synovial fluid pH numbers in each group were analysed according to age (Table VII). The mean pH of the normal fluid of adolescents (under twenty) was $8{\cdot}10\pm0{\cdot}13$, significantly higher than for adults.

SUMMARY

1. The results of viscosity measurements on a number of normal, traumatic and osteoarthritic synovial fluids from human knee joints are described and discussed.

2. A decrease of the viscosity of normal synovial fluid with age has been found.

3. The decrease of the viscosity with age and in the pathological groups is analysed and its relation to the viscous anomaly is considered (Fig. 6).

4. The question whether dilution or depolymerisation is the important factor in decrease of viscosity in these groups, and the value of viscosity measurements as a whole, are discussed.

5. Measurements of pH have been made on the same groups of synovial fluids and on the blood of patients in these groups.

6. The mean values for blood and synovial fluid differ significantly, and the pH of the synovial fluid of adolescents is significantly higher than at other ages.

7. There is no significant difference between the traumatic and osteoarthritic groups, but both are significantly less than the normal.

8. In both fluids the peak frequency in all three groups is the same, that for blood being 7·3 to 7·5 and that for synovial fluid being 7·5 to 7·7 (Fig. 7).

One of us (E. H. J.) is indebted to the Central Research Fund of London University for the purchase of the pH meter and serum electrode.

We are grateful to Dr P. Alexander of the Chester Beatty Research Institute, London, for suggesting the design of the viscometer.

The work was carried out in the Battersea General Hospital and in the Anatomy and Physics Departments of the Royal Free Hospital (London) School of Medicine and we should like to thank Professor R. E. M. Bowden and Dr H. A. B. Simons for the facilities in their departments and for helpful criticisms.

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PHOSPHATASE ACTIVITY IN THE LIMB BONES OF GROWING RABBITS

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In 1923 Robison discovered high concentrations of an enzyme capable of splitting organic monophosphates in the bones of rabbits and rats, and notably in the ossifying cartilage of the epiphysis of the femur. He suggested that this enzyme could be responsible for the deposition of calcium salts in bone by hydrolysing the phosphate esters present in blood and so disturbing the equilibrium between solid calcium phosphate and the solution of calcium and phosphate ions and undissociated calcium phosphate at the site of activity. Since then, evidence has accumulated from many sources, and the association of alkaline phosphatase with the deposition of mineral salts is well attested (Gomori 1939, Lorch 1946, Siffert 1951, Woodard 1956, Bourne 1956), though the detailed mechanism of the process still requires clarification.

Acid phosphatase is present in bone in far less amount, and has attracted correspondingly less attention. There are some indications that it may be linked with bone resorption. Gebala (1956) found raised serum acid phosphatase levels in osteogenesis imperfecta, and suggested that these were due to osteoclastic activity. Changus (1957), in a histochemical study of fibrous dysplasia of bone, found high alkaline phosphatase activity in the osteoblasts, but significant acid phosphatase activity only in osteoclasts, giant cells and macrophages. Before this, Gutman and Gutman (1938) had found that prostatic acid phosphatase was liberated into the blood stream in high concentrations from predominantly osteolytic metastases of prostatic carcinoma and not so much from osteoblastic metastases.

The present quantitative study of phosphatase in rabbit bones supports the concept that alkaline phosphatase is associated with the mineralisation and deposition of new bone. Two forms of acid phosphatase were distinguishable. One fraction (formaldehyde-resistant and tartrate-resistant) has a distribution like that of alkaline phosphatase, suggesting an association with deposition of bone; the other (formaldehyde-stable, tartrate-inhibited) occurs mainly in marrow and cancellous bone, and as much in mature as in young bone: a distribution consistent with its association with bone resorption and remodelling. That the chemical characteristics of this enzyme resemble those of prostatic acid phosphatase may be significant or merely coincidental.

MATERIALS AND METHODS

Healthy male rabbits of known age, from three litters, were killed by breaking their necks. The girdle and limb bones were dissected out, roughly cleaned from adhering soft tissue, and stored in the freezing chamber of a refrigerator for periods of two weeks to six months. Previous investigations had shown no decrease in total acid and alkaline phosphatase activities of bone after twelve months' storage in the refrigerator. Of the present series, the only specimens to be estimated less than three months after dissection were those from a fifteen-months-old rabbit, the oldest of the series. The only specimens in which deterioration seems at all likely are those from a three-weeks-old rabbit, which were involved in a failure of the refrigerator and thawed for a short, but uncertain, time. Thus any discrepancies due to loss of enzyme activity during storage will have tended to decrease the contrast shown here between young and old bones, as the youngest bones were most liable to deterioration, and the oldest least so.

For examination each bone was more carefully cleaned and weighed, and a scale drawing was made. It was then divided on a roughly anatomical basis into portions weighing anything from a few milligrams to over a gramme. Each portion was chopped with nail clippers or

scissors into a weighed specimen tube and reweighed. It was then ground in a small glass or porcelain mortar with an approximately equal weight of washed sand and a measured quantity of distilled water, to give a known dilution weight to volume. Dilutions varied from 1/10 to 1/300 according to the weight of bone available and the expected phosphatase activity. Fine grinding was found to be essential to liberate all the alkaline phosphatase from bone fragments.

PHOSPHATASE ACTIVITY MICROMOLES PER HOUR OF PARA-NITROPHENOL LIBERATED FROM PARA-NITROPHENYL PHOSPHATE PER GRAMME OF BONE	ALKALINE pH 10·3	ACID pH 4·9
	UNDER 10	UNDER 1
	10–20	1–2
	20–40	2–4
	40–60	4–6
	60–80	6–8
	80–100	8–10
	100–200	10–20
	200–400	20–40
	400–600	40–60
	600–800	60–80
	800–1,000	80–100
	OVER 1,000	OVER 100

Key to shading of Figures 1 to 5.

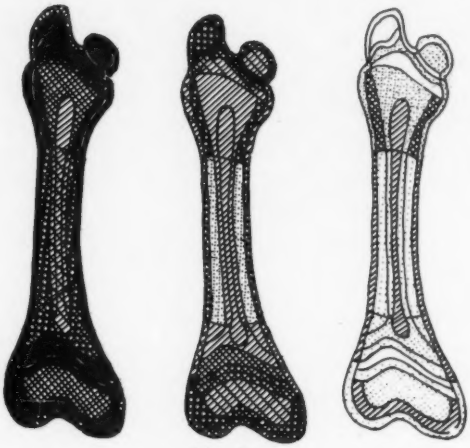

FIG. 1

Right femur of rabbit three weeks old. *Left*—Alkaline phosphatase. *Middle*—Formaldehyde-stable and tartrate-stable acid phosphatase (FTS). *Right*—Formaldehyde-stable, tartrate-inhibited acid phosphatase (FSTI). (Shading as in key.)

Suspensions were stored in the refrigerator overnight; next day they were shaken and centrifuged, and the supernatant was used for phosphatase estimations.

Estimations of para-nitrophenol liberation from para-nitrophenyl phosphate were made by a modification of the method of Bessey, Lowry and Brock (1946): 0·1 millilitre of supernatant was used for each estimation. For alkaline phosphatase activity this was incubated with 1 millilitre of 0·2 per cent (weight to volume) para-nitrophenyl phosphate in glycine buffer at pH 10·3. For acid phosphatase, 0·12 millilitre of 0·33 per cent substrate in citrate buffer at pH 4·9 was used. This gives the same final concentration of substrate, but a concentration of bone extract five times that used for alkaline phosphatase estimations, in accordance with the lower enzyme activity. Most estimations of acid phosphatase were carried out in the presence of 0·5 per cent formaldehyde, since bone acid phosphatase was found to be active with this addition, and it was hoped to eliminate as far as possible any contribution by the erythrocyte acid phosphatase of marrow. Additional estimations in the presence of M/100 tartrate served to separate the formaldehyde-stable acid phosphatase into two components with different distributions. Estimations were made in duplicate wherever the volume of supernatant permitted. Incubation was for thirty minutes, and activity was stopped by the addition of N/2 NaOH, using 3 millilitres for alkaline

TABLE I

PHOSPHATASE ACTIVITY OF RABBIT FEMUR AT DIFFERENT AGES

	Micromoles of p-nitrophenyl phosphate split per hour by 1 gramme of bone									
	pH 10·3 Alkaline phosphatase				pH 4·9 Formaldehyde-stable acid phosphatase					
					Tartrate stable			Tartrate inhibited		
Age in months	¾	3	5	15	¾	5	15	¾	5	15
Articular cartilage of head	1,293	778	354	72	89	3·8	3·8	2·9	0·5	0
Cortex and medulla of head	1,390	290	31	19	33	1·1	0·6	6·5	0·4	1·2
Epiphysial cartilage	1,580	1,930	593	(24)	254	22	(0)	0	2·4	(0·5)
Vascular layer below cartilage	1,840	1,050	1,285	(24)	58	21	(0)	9·2	3·0	(0·5)
Cortex of metaphysis	6,020	100	30	6·5	76	0·9	1·4	49	2·5	2·3
Cortex of shaft	729	35	4	0·5	8·9	0·9	0	3·8	0	0·2
Cortex of lower metaphysis	760	204	92	7·4	18·6	1·6	1·8	4·8	1·8	3·8
Vascular layer above cartilage	1,470	1,090	1,210	—	51	18	—	5·0	6·2	—
Epiphysial cartilage	1,300	1,040	1,030	—	47	16·5	—	0	0·7	—
Medulla of epiphysis	446	126	4·5	(17)	42	0·5	(2·0)	6·8	0·2	(2·6)
Cortex of epiphysis	2,670	425	27	(17)	99	0·9	(2·0)	10·5	1·0	(2·6)
Articular cartilage	930	1,070	765	264	85	8·1	2·9	3·4	1·4	3·8

TABLE I—*continued*

PHOSPHATASE ACTIVITY OF RABBIT FEMUR AT DIFFERENT AGES

	Micromoles of p-nitrophenyl phosphate split per hour by 1 gramme of bone									
	pH 10·3 Alkaline phosphatase				pH 4·9 Formaldehyde-stable acid phosphatase					
					Tartrate stable			Tartrate inhibited		
Age in months . . .	¾	3	5	15	¾	5	15	¾	5	15
Mid-shaft										
Subperiosteal layer . .	4,240	2,130	112	9·6	59	2·9	0·4	13	0	0·4
Cortex	729	35	4	0·5	8·9	0·9	0	3·8	0	0·2
Inner layer	306	563	2·4	3·4	12	0·7	0·3	3·8	0·3	0·6
Marrow	225	91	42	86	14·8	3·0	6·8	14·5	12·3	10·1

and 0·6 millilitre for acid phosphatases. In control tubes the bone extract was added after the addition of alkali. Para-nitrophenol liberation was estimated by comparison with a standard solution in a Spekker absorptiometer, using a mercury vapour lamp, and isolating the violet line at 4,360 A by the use of Ilford filter 601 (transmission 3,850–4,750 A) with the supplementary filter 809 cutting out light between 3,750 and 4,150 A. A semi-micro cell was used for the acid phosphatase readings.

RESULTS

Figures 1 to 5 show quantitative distribution of alkaline and formaldehyde-stable acid phosphatases in femora of rabbits of three weeks, five months and fifteen months of age, and in pelvis and tibia and fibula at five months. Radiographs of the same bones are shown in Figures 6 to 10. Table I gives actual figures for enzyme activity at representative sites in the femur at different ages.

Alkaline phosphatase occurs mainly in the regions of deposition of new bone—next to the epiphysial cartilages and under the periosteum. It is found in the greatest concentrations in young bones, and decreases both in local concentration and in total amount with maturation. Figures 1 to 5 and Table I show the concentration gradients within a bone, and the decline of activity at the same site with increasing age. Figure 11 shows the total alkaline phosphatase activity of the femur at different ages compared with the increase of weight in grammes per month. There is a positive correlation coefficient of 0·87 between the two sets of figures. Similar correlation coefficients for other bones are: pelvis 0·47, tibia and fibula 0·96, pectoral girdle 0·59, each estimated on six pairs of figures. These figures show significant correlation only in the long bones, but if all the observations are treated as one series of twenty-five

pairs of figures, the correlation coefficient is 0·82, which is highly significant, with a probability of occurring by chance of well under 1 in 100, and indicates a real association between alkaline phosphatase activity and weight of bone laid down.

Formaldehyde-stable acid phosphatase—Preliminary investigations showed 75–100 per cent of the total acid phosphatase of rabbit bone to be active in the presence of 0·5 per cent

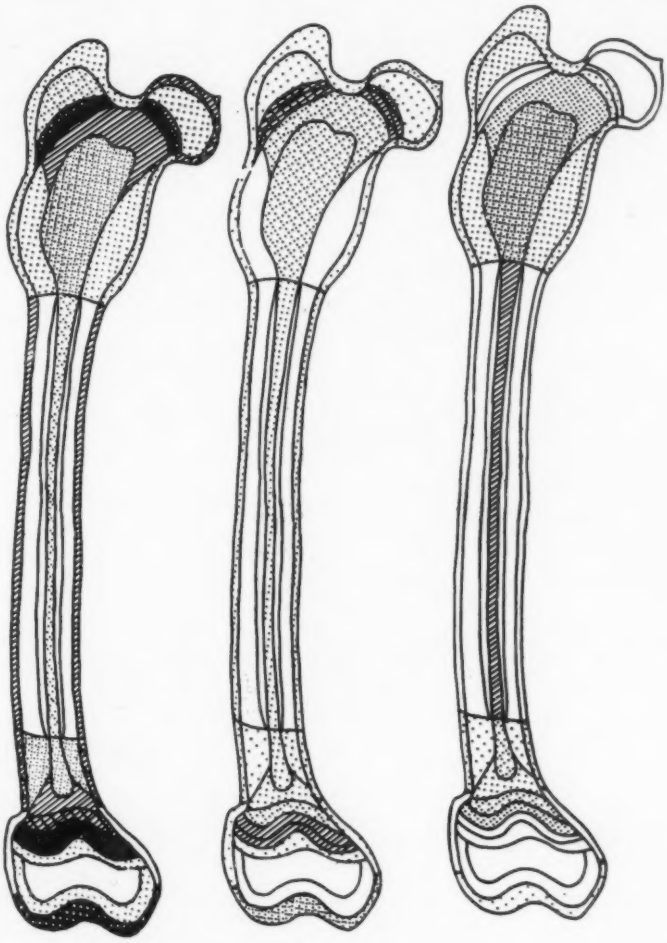

FIG. 2

Right femur of rabbit five months old. *Left*—Alkaline phosphatase. *Middle*—Formaldehyde-stable and tartrate-stable acid phosphatase (FTS). *Right*—Formaldehyde-stable, tartrate-inhibited acid phosphatase (FSTI). (Shading as in key.)

formaldehyde. Laked rabbit erythrocytes showed 39 per cent of their total activity, and additions of laked erythrocytes to bone showed additional activities ranging from 15 per cent to 33 per cent of those obtained in the absence of formaldehyde. Both bone and blood for these experiments had been stored for three weeks in the refrigerator. Experiments on tartrate inhibition with erythrocytes from stored blood were anomalous. One experiment showed 99·6 per cent of total activity in the presence of M/100 tartrate; another showed only 36 per

cent of the activity of the formaldehyde-stable fraction. There is thus a possibility that the formaldehyde-stable, tartrate-inhibited fraction of bone acid phosphatase may be contributed to a considerable extent by erythrocyte acid phosphatase.

Formaldehyde-stable and tartrate-stable acid phosphatase (FTS)—This fraction shows a distribution very like that of alkaline phosphatase, though at far less concentration. In

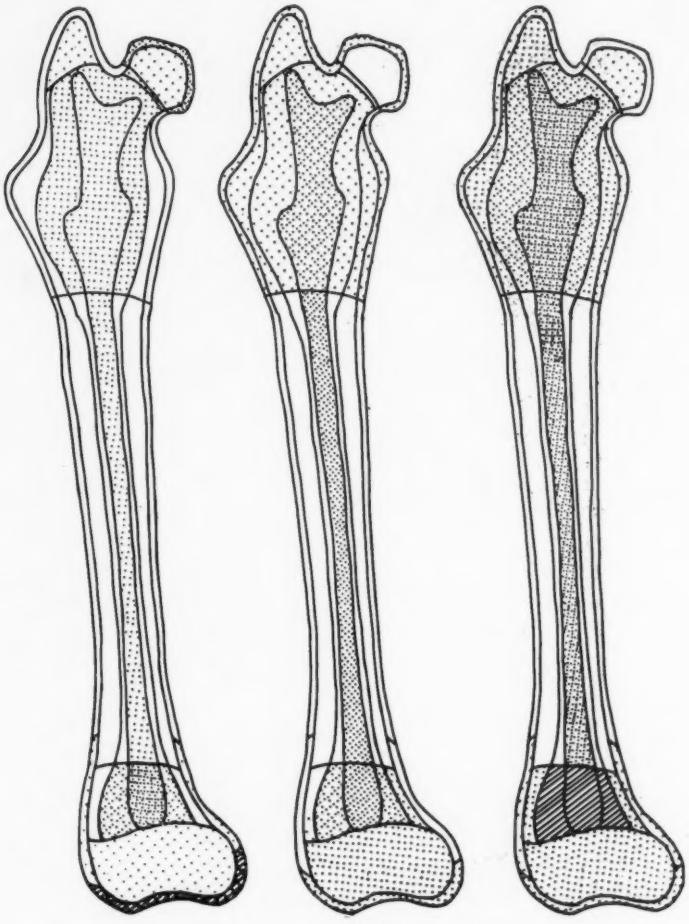

FIG. 3

Right femur of rabbit fifteen months old. *Left*—Alkaline phosphatase. *Middle*—Formaldehyde-stable and tartrate-stable acid phosphatase (FTS). *Right*—Formaldehyde-stable, tartrate-inhibited acid phosphatase (FSTI). (Shading as in key.)

Figures 1 to 5, 1 unit of acid phosphatase is indicated by the same shading as 10 units of alkaline phosphatase, but the FTS diagrams still appear as slightly lighter versions of the alkaline phosphatase diagrams. Table I gives figures for activities at representative points in the femur. It will be seen that, while the distributions are sufficiently alike to give very similar diagrams, the numerical ratio of the activities of the two enzymes varies considerably

(from 1·7 to 450 in one series of estimations). This makes it unlikely that the FTS fraction simply represents the residual activity at pH 4·9 of alkaline phosphatase.

Formaldehyde-stable, tartrate-inhibited acid phosphatase (FSTI)—The distribution of this enzyme is completely different from the two previously considered. It is not concentrated in

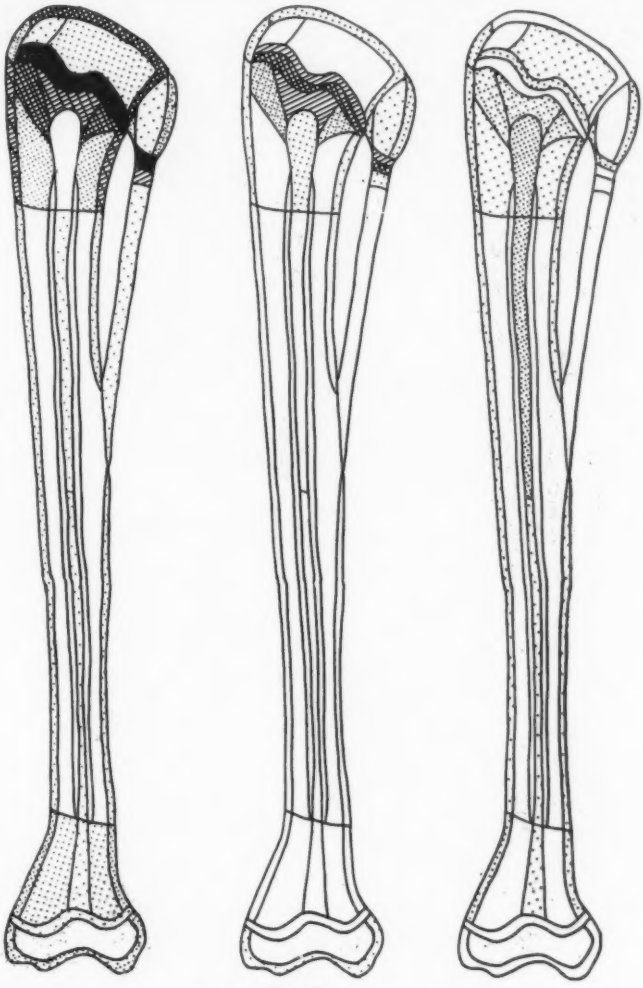

FIG. 4

Right tibia and fibula of rabbit five months old. *Left*—Alkaline phosphatase. *Middle*—Formaldehyde-stable and tartrate-stable acid phosphatase (FTS). *Right*—Formaldehyde-stable, tartrate-inhibited acid phosphatase (FSTI). (Shading as in key.)

areas of deposition of bone, but in marrow and cancellous bone, and, though there may be a slight decrease in local concentrations with bone growth, as shown in Table I, there is no decline in total activity. Figure 12 shows the changing pattern of acid phosphatase activity with growth of the femur. The FTS fraction is initially far higher than FSTI, but it rapidly

declines, while FSTI slowly rises, until about eight months of age, when both reach steady levels, with the FSTI activity about twice that of FTS.

DISCUSSION

The association of alkaline phosphatase with the deposition of new bone is already amply documented (Robison 1923, Gomori 1939, Lorch 1946, Siffert 1951, Woodard 1956, Bourne 1956). The present investigation merely adds some quantitative confirmation to a well attested fact.

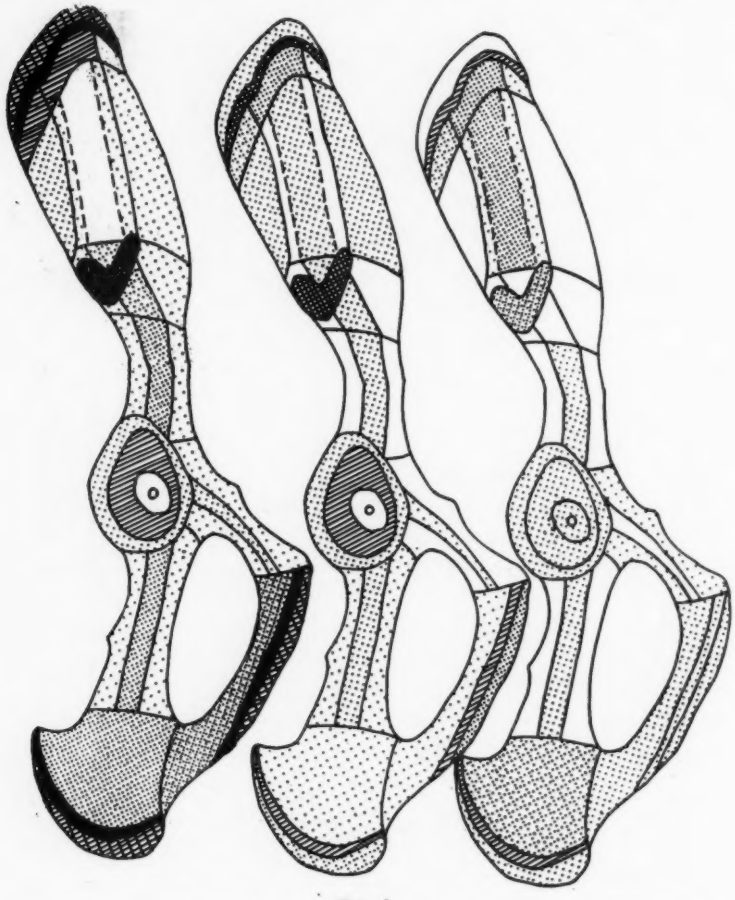

FIG. 5

Right half of pelvis of rabbit five months old. *Left*—Alkaline phosphatase. *Middle*—Formaldehyde-stable and tartrate-stable acid phosphatase (FTS). *Right*—Formaldehyde-stable, tartrate-inhibited acid phosphatase (FSTI). (Shading as in key.)

The position with regard to the acid phosphatases of bone is neither initially nor finally so satisfactory. It was hoped, by the use of 0·5 per cent formaldehyde in the substrate throughout these experiments, to eliminate any contribution made by the erythrocyte acid phosphatase of marrow; but the finding of some formaldehyde-stable acid phosphatase activity in erythrocytes of stored rabbit blood leaves this possibility open. It is clear

that two acid phosphatases are present in bone, which have different distributions and are differently affected by growth and maturation of the bones. It seems likely that the enzyme FTS which is found along with alkaline phosphatase in areas of deposition of new bone, will have some association with that activity. The tartrate-inhibited fraction (FSTI), found

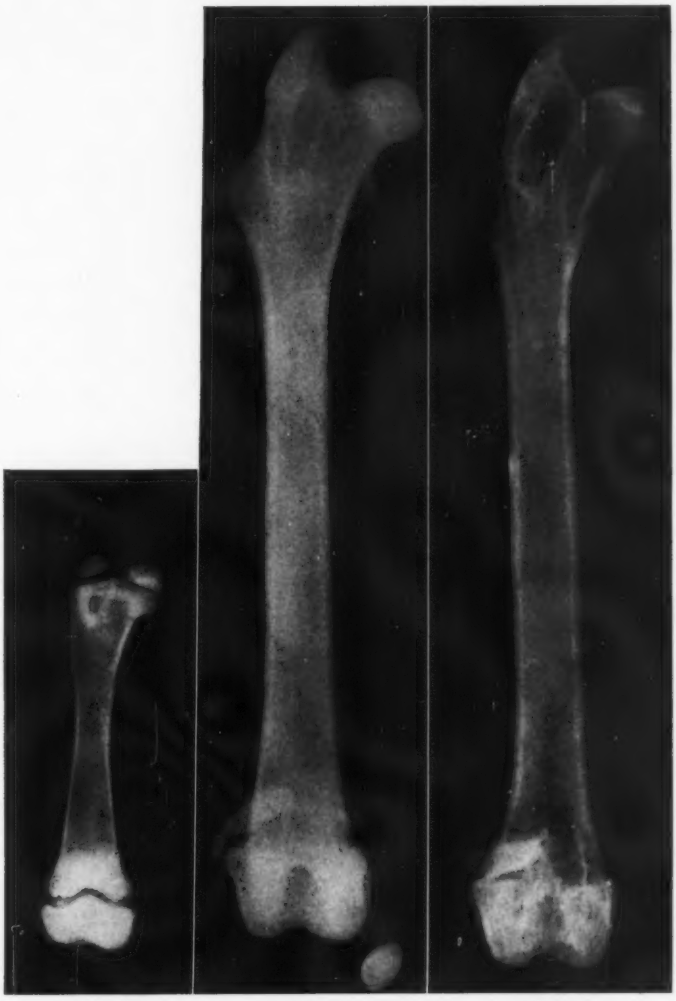

FIG. 6 FIG. 7 FIG. 8

Radiographs of rabbit femora. Figure 6—Three weeks old. Figure 7—Five months old. Figure 8—Fifteen months old.

mainly in red marrow and cancellous bone, poses more of a problem. It may represent the residual activity under these conditions of the acid phosphatase of developing erythrocytes. Even if this were so it could have an effect on remodelling and resorption of bone, and it is tempting to suppose this to be its chief function, particularly in view of the high acid phosphatase activity found in osteoclasts by Changus (1957). It is tempting, too, to speculate on the

likeness of this enzyme to the acid phosphatase of the prostate, which is also formaldehyde-stable and tartrate-inhibited (Abul-Fadl and King 1949), and which, in carcinoma of the prostate, is liberated into the blood stream in high concentrations mainly from osteolytic

FIG. 9 FIG. 10

Radiographs of rabbit bones five months old. Figure 9—Tibia and fibula. Figure 10—Right half of pelvis.

metastases, the predominantly osteoblastic metastases not producing such a marked rise (Gutman and Gutman 1938). There is as yet insufficient evidence in support of these tentative suggestions.

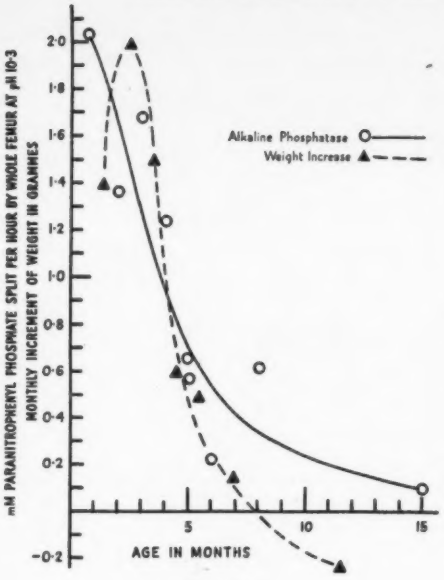
mM PARANITROPHENYL PHOSPHATE SPLIT PER HOUR BY WHOLE FEMUR AT pH 10·3
MONTHLY INCREMENT OF WEIGHT IN GRAMMES
Alkaline Phosphatase
Weight Increase
AGE IN MONTHS

FIG. 11
Alkaline phosphatase and bone growth.

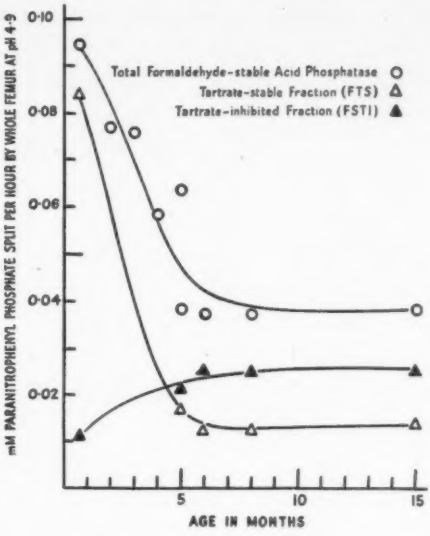
mM PARANITROPHENYL PHOSPHATE SPLIT PER HOUR BY WHOLE FEMUR AT pH 4·9
Total Formaldehyde-stable Acid Phosphatase
Tartrate-stable Fraction (FTS)
Tartrate-inhibited Fraction (FSTI)
AGE IN MONTHS

FIG. 12
Acid phosphatase and age of bone.

SUMMARY

1. A quantitative study of phosphatase distribution in the limb bones of growing rabbits is reported.

2. Alkaline phosphatase is present in high concentrations in areas of deposition of new bone. Both local concentrations and the total alkaline phosphatase content of a bone are found to decrease with age. There is good correlation between total alkaline phosphatase activity and monthly increment of weight.

3. Acid phosphatase is present in these bones in greatly less concentrations than alkaline phosphatase.

4. The acid phosphatase of bone shows nearly full activity in the presence of 0·5 per cent formaldehyde. It can be subdivided into two enzymes with characteristically different distributions by the effect of M/100 tartrate on activity.

5. The formaldehyde-stable and tartrate-stable acid phosphatase of rabbit bone (FTS) has a distribution very similar to that of alkaline phosphatase, though very much less in amount, and, like the latter, declines in activity as the bone matures.

6. Tartrate-inhibited, formaldehyde-stable acid phosphatase (FSTI) is found mainly in red marrow and cancellous bone, and full activity persists in mature bone. This enzyme may be associated with resorption and remodelling of bone, or it may represent residual activity under these conditions of the acid phosphatase of developing erythrocytes in the marrow.

This work was supported by a grant from the British Empire Cancer Campaign. I wish to thank Dr C. H. G. Price for his advice and interest, Mr J. E. Hancock for the production of radiographs and of photographs of the diagrams, and Miss E. H. L. Duncan for help with statistics.

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THE CROOKEDNESS CLINIC OF NICHOLAS AND PETER SCHOT

WILLIAM BROCKBANK, MANCHESTER, ENGLAND

There can be no better way of learning about doctors, patients and the sick-room than by reading contemporary diaries, particularly those written by parsons. An interesting example is the case note on sixteen-year-old Edmund Verney, son of Sir Ralph Verney of Claydon House. The story can be found in the third volume of *The Memoirs of the Verney Family during the Commonwealth*, compiled from family letters and documents by Margaret Maria Lady Verney, published in 1894.

Mun, as he was called, was born on Christmas Day, 1636. Two years later he was described as " a strapping boy giving promise of health and long life." He was brought up by his grandmother. At the age of three he was " rustic and bashful " and his parents, who were strangers to him, were disappointed that he did not take to them. The old lady pleaded for her " sweet child " and begged his father not to whip him. " Be shore that he is not frited by no menes: he is of a gentle sweet nature sone corrected." He was a fine tall boy at the age of seven and at eleven he was described as thriving in stature and learning. His mother died when he was fourteen, and shortly afterwards he was taken by his father on a grand tour abroad.

He was completing another tour at the age of sixteen with his father and tutor, Dr Creighton, D.D., when the relevant passages commence. Dr Creighton, a Royalist in exile, afterwards became the Bishop of Bath and Wells. Lady Verney takes up the story:

> " December 24, 1652. As we have seen he (Sir Ralph) left Mun at the Hague with Dr Creighton, and they went on to Utrecht. The boy was overgrown and weak; his ' governor ' wishes to consult Myen Herr Skatt (or Schott), who has a great reputation at Utrecht for his treatment of crooked children. ' If they be young,' writes Dr Creighton, ' the sooner are they cured, and he selldome undertakes old people, becaus invetrat ills especiallie when they come by nature are hardlie removed; yett hath he done such cures to wonder, upon some of 50 yeares and upward, but selldomer: from the craddle to the ages of 30 or 40 ar his patients, all sexes, ranks, qualities, and conditiones, and young people have beene brought to him from further then the uttmost parts of Shettland or the Orcades, even from Swedland, Denmark, Holsteyne, &c. And this is his way, If when he look upon the partie he fynd the defect curable he undertaks it, and wth out bargayne expects such an honest reward as the partie is or willing or able to bestow; and trulie I could never lerne or heare but that he was an exceeding honest conscientious man. If he sees nature so defective or so much collapsed that it is incurable, he will not undertake it.' " . . .
>
> January 28, 1652. Dr Creighton is writing:
>
> " Truly I wold never have thought he could have beene so crooked if I had not seene (it). The backbone in which all the fault lies is quyt awry and his right shoulder half a handfull lower at least than his left. Herr Skatt hath undertaken the cure, if your sonne will stay heere three quarters of a yeare; and alreadie he is about to make harnessing for him which your soone is very willinge for ought I can perceive to undergo."
>
> Sir Ralph Verney to Dr Creighton, February 18, 1652(3).
>
> " I thanke you for your care of Muns crookednesse if you (upon conferring with others that have had experience of y^{e} Mans practises) conceive hee can cure Mun, soe as to make him absolutely streight, I am content he should begin the cure as soone as

you and hee thinke fit but I think it necessary that you should first know what hee expects for his reward least hee proove unreasonable afterwards; for tis usual with some of that profession, to make very imoderate demands, not only for theire paines and skill but also for such bathes, Oyntments, Irons, and such like matters as shall bee requisite for the worke. In my opinion tis best agreeing with him for altogether in grosse. I pray informe me what you doe in this as soone as conveniently you can."

Dr R. Creighton to Sir Ralph Verney, February 18, 1652.

" Mr Verney is very well god be praised, and this day hath enterd his harness; that rare man hath wrought a miracle upon my L.(ord) Gerard, and to him fr. all parts of Europe people flock in great abundance. He doubts nothing of Mr V."

Dr R. Creighton to Sir Ralph Verney, February 4, 1652.

" I could not agree with Mr Skatt as you commanded in yo^{r} le^{rs}, nor doth he bargayne (?) wth any man, it is not his custome, nor manner of proceeding: and in that poynt he is very superstitious: If he cannot cure, though he upon entreatie may trie and miss, yett he taks nothing, accounts his labo^{r} lost, and if he do cure, as he is so judicious that he hardlie undertaks anything what he brings not to pass, then he taks so reasoneable (as I am enformed by all that know him, and in speciall by an English chirurgian who lives heere, and is a kynd of retayner to his house) that they who receive benefitt by him ar willing oftymes to give more then he is willing to take. He hath beene in harness two weeks, so fynely fitted for his crookedness as yett I never saw any thing: It is perfyt massive irone all along (excepting su^{m} holes heere and ther, wheer he pleaseth) back and breast, lyned wth quilted fustiane and all so light as is wonderfull: This I say he hath worne two weekes, and su^{m} dayes: At first when he putt them on, he fellt no payne, or pressure at all, but at (?) upon his haunchebone of his left syde, wher the arm^{r} to keepe him up towards the right syde, gav him a little twitch now and then upon that bone. Mr V. wold fayne have had it cutt a little shorter, but Mr Skatt wold in no wayes be brought unto it: in less then a weeke that payn went away, and then he fellt his harness su^{m} what loose upon him, wherupon we the second tyme went to him to lett him see, who streithned it, by pinning sum iron buttones closer, and drawing sum strings, but then Mr V. fellt greate payne in his right shoulder then befor he hade fellt on his haunchebone, insomuch that all night he slept very ill, it lay so hard upon that shoulder, and yett I could not obtayne the relaxation of one hayre bredthe and now the payne is allmost quyte gone, he playes on the Lute, follwes his other studies, goes abroade, to dinner, to the fields, enjoyes his health, God be praised, and is what he was befor, only that right arme he can scarcely raise to combe his heade, by reason of the straitness of that harness towards the right shoulder: And Mr Skatt doth not doubt but to make him as straight, as any in Christendom wth in these six Moneths and less, once he sayd nyne Moneths now he says six: and when you pay him you ar in the same condition wth My L. Ger: and thowsands more that flock to him from all parts of Germany and Denmark: For he never makes bargaynes and to do as others, as all men do, I hope you will not think it amiss: Mr V. weares his harness under his doublett very patiently, more than I ever expected: and truly Sir, he is no ill conditioned youth: I have beene in his company now six Moneths full, and I know not any vice in the world to w^{ch} he is inclined: extreamly civill, and free fro all intemperance; eates his meate hartily, drinks very little wyne, grows tall apace, but will shoote out extremely, when his crookedness is gone, w^{ch} did not a little pinch and hold back his growth: One thing I must putt you in mynd off, you did ill forgett, that shute of cloath w^{ch} I so often wrott to you for, and w^{ch} you promised to send: and you must take heede what you promise to young men, who will daily call for a performance, his last cloth sute w^{ch} I made heere I gott the

tailor to lett it out in the seames for his harness, and becaus he could weare no waistcoate wth that harness, and his armes were all bare but his shirt and doublett, I made him a payr of sleeves of scarlet bayes, to keep him warme, w^{ch} he weares night and day: For Mr Skatt desired he should be kept fro cold, eate no badd meate, no oysters, nor such things as might endanger his health, or hinder his purposes towards him. I have bought him su^{m} few books too: he hath redd Salust all over and over, and is now in Livy, w^{ch} I have bought him wth Ceaesar's Commentaries and Quintilian at an auctione of books, this last weeke, and he goeth on very well in his booke and lute, other exercises as yett we have undertoke none, by reason of his straightgirding as I have told you: wth in a moneth or so I beleeve we shall fence at the fenceing schoole, w^{ch} Mr Skatt will allow him so soone as he is able to stirr his armes as he should, and that art requires, but he will not suffer him in any case to dance till he be perfytly cured and past his help or art."

Lady Verney once more takes up the story.

" July 8, 1653. Mun's harness is very irksome, especially in hot weather, and he complains that it galls him: but his governor reports in six months' time: ' I may truly say the cure is allmost perfyted, yet whilst he is under Herr Skatt, I think it wer no wayes for his good to remove him. My intention was to convey him to Leyden for his learneing, but I now conceive it was God's great mercie to send us hither from the Hague for rectifeeing of his body; the soule will (I hope) follow the better.'

" July 15, 1653. Dr Creighton writes again: ' He is very well, grows apace, and of his crookedness so allmost wholly restored, that very little difference is to be seene; and when his clothes and cloak is on without his harness none at all, yet he weares his harness for the most part continuallie, and must I am afrayed till the next spring by which tyme Her Skatt doth not doubt but to make him a perfyt man: and in the meane tyme becaus the weather is very hott in these moneths, he permitts him sum tymes for a two or 3 dayes together ease him self of his harness, and go in his single doublett, which I say he condiscends unto meerly to ease him from wearing iron bodies continuallie, though they be very light, and I think might well be borne at all tymes, and wer farr better borne, then left off at any time till the cure be finished.'

" The discomforts which the tutor felt were so easy (for somebody else) to bear come out vividly in Mun's letters, though the boy does not complain. The iron body fits tightly back and front, lined with soft leather; it is fastened by Herr Skatt over his linen shirt; Mun can neither undo it nor ease any undue pressure. His shirt in hot weather is always wet, but he cannot change it. Once a week he goes with his clean shirt over his arm, to have the armour taken off: his shirt and the leather lining are then ' as black as a chimney.' It does not appear that the skin was washed even at the weekly dressing, only that the leather lining was renewed. Sir Ralph asks whether the shirt could not be changed twice a week, but Mun replies that the great man has more than 2000 patients—men and women, boys and girls—that he could never get through his work if they all came twice a week, and that many keep on the harness for a month together.

" The tutor continues his report: ' He growes apace upon my worde; in height ther is but little difference betweene him and I. He loves his ease very well, and his owne will above all things and though in truth I cannot accuse him of any vice or scandall, he is civill and temperat, yet he loves his bedd too well, and is very willfull, for the which two defaults I entreat you hartilie to chide him, for upon my worde he deserves it.'

" January 1654. Myen Herr Schott's bill is a heavy one (Dr Creighton writes) ' he is at great charges in maintayning 16 or 17 servants daily, and three sonnes very expert in his art, that do nothing but work in iron and steele, and brace and unbrace crooked limbs. They who have received benefitt by him use to present him with a goode peece of plate, or perhapps a round summe of monie, over and above his accounts; which they do

cheerfullie, and he receives thankfullie, for he is noe unrasonable man. He hath done a notable cure on Mr Verney.'

" March 20, 1654. Mun manages to dance girt in his armour."

In May 1656 Edmund Verney returned home, a young man in his twentieth year. He had an affectionate and pleasant temper, he was tall and handsome, but somewhat clumsily and heavily built, and his awkwardness of manner and slovenliness of dress were a great trouble to his precise and gentlemanlike father.

" February 15, 1657. Herr Schott had come to London from Utrecht, and the ' bodies ' at 30/ the pair, which Mun still wore, were the heaviest of his expenses.

" March 5, 1657. Dancing lessons from Moulin, a fashionable French master, are strongly recommended; Mun agrees but his steel bodies make dancing almost too painful."

Poor Mun's luck never returned. He was shabby and untidy in his dress. When he was twenty his father wrote: " Mun is not at all nice either in point of bewty or breeding nor must that woman be so that marries him." He put on weight, reaching more than twenty stones. In spite of that he did find a wife and had three children. But they all died young and he himself failed to outlive his father, dying in 1688 at the age of fifty-one.

The curious reader has been left to wonder what sort of a person was " Myen Herr Skatt (or Schott)." E. M. Little was shown the correspondence by Lady Verney in 1903 and wrote an article on the subject. But though he made inquiries in Utrecht no trace of him could be found. He was satisfied that Schott was not a professional man, for in spite of his skill both Sir Ralph and Dr Creighton referred to him as " the man," a phrase which neither of them applied to physicians or surgeons when these were mentioned in other letters. He thought he must have been an artificer, probably an armourer who made steel " bodies " or " harness " something like the breast-plates and back pieces which were at that time worn by soldiers.

Some months ago I took up the trail myself but for a time met with no more success. Then one day my question reached the archivist of the town, Mr J. W. C. van Campen. I am most grateful to him for the following information. Claes (or Nicholas) and Peter Schot, sons of Jacob Claes Schot, had a great reputation as makers of orthopaedic appliances. Mr van Campen believes they were medical men. The Town Council decided on July 30, 1655, that the supplication of Nicholas and Peter Schot be granted out of consideration of their art. The brothers had asked for permission to mend the iron, copper or other instruments made by them to cure crooked hunchbacked and otherwise malformed limbs in their own house without interference from the Smiths' Guild. They stated that many people came to Utrecht from elsewhere to be healed by their art.

The Guild protested against this inroad on their monopoly and the Town Council decided that the brothers Schot should continue to make their instruments although they were not members of the Guild provided they gave instead 16 guilders to the poor of the Guild and the dues of the Guild to the Chairman and Examiners. In addition they had to promise not to accept any journeymen or apprentices who had not fulfilled their financial obligations towards their masters.

Peter died in August 1662, but Nicholas was allowed to continue his work on the same terms. A further record occurs in the Council's proceedings on June 25, 1666: " The Town Council takes into consideration that Nicholas Schot, a skilful doctor of crooked and dislocated limbs, has settled in this town, wherefore many people of importance come and stay here to be cured. To acknowledge this it has been decided to grant him freedom from taxes for all the wine and beer consumed in his household." At the same time the Town Council ordered the burgomasters to request the same freedom of taxes from the Provincial Council. This demand was considered on July 4, 1666, and referred to the Gedeputeerde Staten (a committee dealing with the daily administration of the province). But no resolution

can be traced. It is clear from this that the Town valued greatly the work of Myen Herr Schot and met him half-way when there was possibly a danger that he would transfer his clinic elsewhere.

E. M. Little comments on a curious sidelight to this story. It seems odd that not one of the many patients who attended the clinic has left a record of the occurrence. There were two thousand patients attending at one time and they included English noblemen. What a pity it was that the " English Chirurgion " who was " a kynd of retayner of his house " has left no record of the brothers' clinics. But possibly one day further details will become available of this busy and successful orthopaedic clinic that existed nearly a century before the word orthopaedia was coined.

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IN MEMORIAM

VERNON KENT DRENNAN
1911-1958

V. K. Drennan, consultant orthopaedic surgeon to the Clwyd and Deeside Hospital area, died at the Northern Hospital, Liverpool, on December 19, 1958, at the age of forty-seven.

Born in Liverpool, he was educated at the Liverpool Collegiate School, studied medicine at Liverpool University, graduated M.B., Ch.B. in 1935, and, after holding resident posts at the Stanley and Walton Hospitals, entered the School Medical Service. In July 1939 he joined the Territorial Army as regimental medical officer to an anti-tank regiment and served in Malaya, India and Burma, first as surgeon to a casualty clearing station and later as surgical specialist in charge of a mobile surgical unit. After the war he was appointed Resident Surgical Officer at Walton Hospital, Liverpool, and in 1948 he obtained the F.R.C.S. (Edinburgh). He was then attracted to orthopaedic surgery and was appointed orthopaedic registrar at Bootle Hospital. He obtained his M.Ch.(Orth.) in 1950 and in 1951 was appointed to the post of consultant orthopaedic surgeon to the Clwyd and Deeside Hospital Group. In 1947 Drennan joined the 8th (Liverpool) General Hospital, R.A.M.C.T.A. At first he was surgical specialist and later was promoted to Lieutenant-Colonel in charge of the surgical division. In 1955 he was further promoted to the rank of Colonel in command of the hospital and in 1957 he was awarded the T.D.

All those who knew Drennan will particularly remember his outstanding attributes—cheerfulness, vitality, artistry and courage. His cheerful, smiling, chubby countenance and his wide scope of invigorating interests made him welcome in any company and brought him many friends in all walks of life. His vitality was remarkable; he carried out his duties as consultant virtually without trained assistance yet attended to his many commitments to the territorial army with zeal, and still found time to become an expert angler. Drennan was passionately fond of music and was an accomplished pianist. His artistry, however, was not a thing of the spirit only but was also combined with an unusual degree of manual skill revealed in the products he designed and created in his own workshop, and which ranged from household furniture to electronic equipment, and manifest also in the operation theatre. His courage was a source of repeated wonder to his friends. For the last three years he had been aware of the fatal nature of his illness, yet this only seemed to stimulate him to greater activity. Towards the end his waning strength could be restored only by repeated blood transfusions. It was with extreme reluctance that he would agree to remain overnight in the hospital to receive these transfusions, and his only complaints were of the interruption to his activities which these visits involved. His loss will be deeply felt by very many friends and grateful patients.

He leaves a widow and two children to whom our sincerest sympathies are extended.

G. E. T.

PROCEEDINGS AND REPORTS OF UNIVERSITIES COLLEGES, COUNCILS AND ASSOCIATIONS

GREAT BRITAIN

BRITISH ORTHOPAEDIC ASSOCIATION

REPORT OF 1958 TRAVELLING SCHOLAR

Mr Charles Manning, the first scholar appointed by the British Orthopaedic Association to visit centres in Great Britain and Europe, writes:

The British Orthopaedic Association Travelling Scholarship enabled me to pursue two objectives: to see and hear more about the treatment of spinal tuberculosis, in particular operative treatment; and to see as much as possible of general orthopaedics in Europe.

I visited certain centres in England first, to meet especially those surgeons with a primary interest in skeletal tuberculosis. Mr M. C. Wilkinson at Black Notley showed me cases in his wards and discussed his views on the direct surgical treatment of spinal tuberculosis. I was also able to visit Mr R. Roaf at Oswestry, Mr E. W. Somerville at the Nuffield Orthopaedic Centre at Oxford, and Mr D. E. MacRae at the Henry Gauvain Hospital, Alton. All these surgeons very kindly gave me much of their time in demonstrating, by operation and in discussion, their views on spinal tuberculosis. This gave me a useful basis for comparison with the views of Continental surgeons when I visited them later. I also visited Mr R. G. Pulvertaft at Harlow Wood Hospital and had an opportunity of discussing with him many aspects of hand surgery. I then spent a week in Exeter where I was cordially received by Mr Norman Capener, Mr F. C. Durbin, Mr G. Blundell Jones and Mr C. C. Jeffery: a full programme had been arranged in the orthopaedic and accident services and visits were made to other units in the area, including the Dame Hannah Rogers School for children with cerebral palsy, the St Loyes College for Rehabilitation and the excellent Devonian orthopaedic workshops. I was most impressed by the wealth of cases of great orthopaedic interest in Exeter, and my week there was an excellent foretaste of my experiences in other countries later.

I spent three weeks in Paris, mainly at Professor R. Merle d'Aubigné's unit at the Hôpital Cochin. There I saw a great variety of orthopaedic and traumatic cases of all kinds. As in Exeter, I had full access to out-patient and follow-up clinics as well as to operations and lectures and animated discussions. Of particular interest were examples of Professor Merle d'Aubigné's development of tibial transposition grafts after excision of the lower end of femur for bone tumour, and anterior fusion with bone graft and long screw for spondylolisthesis. A useful device which I saw only in Paris hospitals was a vacuum bottle attached to polythene tubing for wound drainage after operations. I was able to visit a number of other surgeons in Paris, including Professor J. Cauchoix at the Hôpital St Louis, and Dr P. Petit and Dr P. Queneau at the Hôpital des Enfants Assistés, who reviewed critically a large series of patients with congenital dislocation of the hip. Reduced prints of radiographs joined together in chronological order made it easy to follow the progress of the condition. Many patients had been watched for over twenty years, but Dr Petit does not intend to publish any details until his follow-up is still longer. Their methods on the whole are conservative, but when operation is considered necessary they prefer a complete exposure of the hip and have found a number of factors preventing perfect reduction. Dr P. Masse at the Hôpital Brettenau and at a children's hospital and paraplegia centre at Fontainebleau showed me his patients; in particular I saw a number of paraplegic patients who had developed masses of new bone about both hips and knees but had very good function after excision of the bony masses.

Professor R. Judet and Dr V. Benassy also showed me their patients at Garches, an orthopaedic and paraplegic centre a few miles outside Paris. Professor Judet demonstrated his new oblique hip prosthesis, which he has found eliminates movements of the stem in the femur. At present he is mainly concerned about the progression of osteoarthritic changes in the acetabulum after operation, but is hopeful that the insertion of preserved human skin between the head of the prosthesis and the acetabulum will eliminate this difficulty.

Professor Cauchoix invited me to spend some days at Berck on the north coast, where three hospitals cater for most of the bone and joint tuberculosis in France. We stayed in the Institut Calôt, the smallest of the three but, I think, the most active surgically. This monthly visit of Professor Cauchoix was filled with work, both operative and clinical, and there was excellent discussion about scoliosis. In two patients with tuberculosis of the spine the lesion was exposed and curetted; in one the lumbo-sacral joint was affected, and after curettage the joint was fused with a massive full-thickness iliac graft. Two patients with scoliosis had spinal fusion after plaster correction, strut grafts being used in addition to autogenous cancellous bone from the ilium. We were all most hospitably looked after by the members of the religious order running the hospital.

My next visit was to Professor F. Pauwels at Aachen, who was most hospitable and spoke excellent French to me because I could not speak German. Professor Pauwels explained his theories about muscle forces and the production of pain in degenerative arthritis of the hip and demonstrated his views at operation, and he gave me a number of most useful tips from his long experience in surgery.

The next centre was Vienna, and there I was based on the Orthopaedic Hospital under the direction of Professor P. J. Erlacher. This is a convent hospital on the southern outskirts of Vienna, where Professor Erlacher has 150 beds, with about ten assistants. His wards are full of most interesting orthopaedic patients, though nowadays very few of them are tuberculous. As in many centres, the day starts at eight o'clock with study of radiographs by the whole staff, and the cases of the day before are discussed. Many children with congenital dislocation of the hip are treated in Vienna, and now few are seen after the age of six months: indeed, the average age for children to be presented for treatment in Vienna itself is now only one week after birth. Professor Erlacher also talked to me about his views on tuberculosis. He recalled that he had started operating directly on the focus in spinal tuberculosis as early as 1934.

While in Vienna I visited Professor L. Böhler at the Workmen's Accident Hospital. He spoke particularly of his views about rest for fractures and bone infection. He has eighty beds with twenty assistants, and 500 out-patients attend this hospital daily. There is a new Workmen's Accident Hospital built since the war by the workmen's compensation insurance authority. Dr O. Russe is in charge of this new hospital which has 280 beds and twenty-four assistants. They have a good system of receiving the seriously injured: the ambulance enters a weatherproof compartment in the basement, the patients being then rapidly transferred by lift to the ward or to the resuscitation room for the operation theatre, or to the ordinary minor dressing station.

I also visited Dr I. Chiari at the General Hospital, who has eighty orthopaedic beds and sees 100 out-patients every day. He had about ten assistants. Lorenz's orthopaedic department in this same hospital had consisted of two rooms and access to five beds when the general surgeons allowed it. I was most impressed by the thoughtful work being done in this unit, and Dr Chiari very kindly performed his fifty-fourth pelvic osteotomy for congenital dislocation of hip for my benefit.

In Florence I visited Professor O. Scaglietti at the Instituto Orthopedica, Toscano, where about 200 beds overflow an old villa in the hills above Florence with a wonderful outlook. This is a very busy hospital with about thirty assistants, every type of orthopaedics as well as injuries being treated. I was privileged to see some of Professor Scaglietti's filming during operations on congenital dislocation of the hip. I was much impressed by both the conservative and operative treatment of the condition in Florence. A new orthopaedic hospital is already being built which will have 350 beds, four operating theatres and excellent accommodation for seventeen visitors.

I visited the Instituto Rizzoli at Bologna where Professor R. Zanoli took me on his grand round, which was preceded by a discussion of radiographs. There are about fifty assistants but there are 620 beds and almost every case seemed to present a major orthopaedic problem. Here I also saw the wonderful orthopaedic workshops that produce a vast amount of orthopaedic appliances every year.

Then to Lyons where I visited Professor M. Guilleminet's orthopaedic unit, seeing there an excellent review of a number of different conditions including congenital pseudarthrosis of the tibia, of which Professor Guilleminet personally has successfully treated fifteen cases. I saw him perform a Milch-Batchelor pseudarthrosis with internal fixation for osteoarthritis of the hip. I also had excellent opportunities for discussing cases with Dr P. Stagnara and in particular the problems of reconstruction after poliomyelitis and scoliosis. Like his chief, Dr Stagnara operates with great gentleness and little loss of blood.

From Lyons I went to Heidelberg where the Orthopaedic Hospital is under the direction of Professor K. Lindemann. This hospital of 420 beds with a medical staff of twenty has attached, in the same group of buildings, accommodation for 100 male and 100 female handicapped children and young adults who receive general education as well as technical training. Professor Lindemann himself is particularly interested in the problem of osteoarthritis of the hip, and is impressed by Professor Pauwel's views on muscle pull as a cause of pain in that condition. I saw him perform one operation in which he separated the muscles from the upper end of femur. This he has performed

in a number of patients who are being carefully followed up. The senior assistants were specialising in certain aspects of orthopaedics. Heidelberg possesses a most active and progressive surgical appliance workshop and has produced the pneumatic arm developed by Mr O. Haefner, an engineer, working with Dr E. Marquardt, an orthopaedic surgeon. Liquid carbon dioxide, contained in 6-inch aluminium flasks, is connected by thin rubber tubing to bellows, the inflation of which can be used to move a joint; this appliance is designed particularly for loss of both upper limbs and it is preferable if the patient has an above- or below-elbow stump. I saw, however, a twenty-four-year-old Polish man who had had a disarticulation at each shoulder ten years before, after an accident; after using the prosthesis on one side for six weeks he could eat and use the lavatory alone, having been previously completely dependent on others. He was able to produce elbow flexion, forearm rotation, and pinch between the thumb and fingers.

I spent two weeks in Copenhagen, mainly at the Orthopaedic Hospital. Unfortunately Professor A. Bertelsen was away, but I was very hospitably received by Dr K. Jansen, Dr H. Larsen, Dr J. Mortens and also Dr B. Rasmussen in charge of hand surgery. There is an excellent junior staff at this hospital and a great deal of friendly rivalry and differing opinions in the treatment of many conditions, for instance scoliosis. Some interesting work was being carried out on arthrogryposis and I saw most encouraging results of conservative operations, particularly on the knees and hands. I was also impressed by the treatment of club foot: operative intervention, varying from simple elongation of the tendo calcaneus to extensive soft-tissue release which included division of the talo-calcaneal interosseous ligaments, was undertaken at an early age in recalcitrant cases. I saw examples of good results in patients treated entirely conservatively and by a combination of surgery and conservative treatment in young children. All types of orthopaedic abnormality are treated in this hospital, but not injuries.

I also visited the excellent workshops and saw several examples of the Canadian prosthesis for disarticulation at the hip working excellently even in old patients, also the Swedish type of hydraulic knee joints.

I visited the cripples' training centre in Copenhagen where 150 girls and 100 boys are training. In charge of the centre is Mr Tachau, who himself is disabled, and we had an interesting talk about the best type of motor-propelled vehicle for disabled people.

I also visited Dr J. Meyer at the Finsen Institute, who discussed the treatment of tuberculosis and showed me his wards. He has a special interest in tumours of bones, and I was invited to attend a conference with the radiotherapists, seeing several most interesting patients. I also visited Dr Meyer's seaside hospital at Karlandberg, overlooking a small inlet on the west coast. There were few tuberculous patients in the hospital at the time, but a number of patients with Perthes' disease, and Dr Meyer and his assistants have done much original investigation into this condition. I was shown a remarkable series of radiographs, and it seemed that Dr Meyer was beginning to be able to give an idea of prognosis from the early films.

I saw the new county hospital recently built at Glostrup, a few miles outside Copenhagen—one of the most modern in Europe, which incorporated many good ideas in hospital architecture and design. The architects were Finnish.

Then I travelled to Jutland to the Orthopaedic Hospital at Aarhus under the direction of Professor E. Thomasen, who kindly invited me to stay in a guest room in the hospital. This is an active unit with assistants to some extent specialising in certain aspects of orthopaedics. Here also a daily conference is held and all medical staff meet every day for lunch, and many subjects were discussed freely, both medical and non-medical. I was able to attend operating sessions, ward rounds and out-patient follow-up clinics, and saw examples of myotonia, a subject in which Professor Thomasen is particularly interested.

I also visited a hospital being reconstructed at Holstrobro to which Professor Thomasen's senior assistant, Dr H. Erikson, has been appointed orthopaedic surgeon. From a surgical point of view the construction and lay-out of the orthopaedic wards and out-patient department appealed to me more than those in the hospital at Glostrup.

I was also taken to a country hospital for long-stay cases originally built as an internment camp for British and Germans during the 1914–18 war. In addition to such conditions as Perthes' disease and rheumatoid arthritis, some mental disease is being treated without segregation. There is also a historically interesting collection of physiotherapy apparatus mechanically driven by moving belts powered by electricity, and a small modern rehabilitation unit planned on lines to ensure easy return to domestic work in patients' own homes.

I visited the seaside tuberculosis hospital at Julesminde, where Dr H. Thomsen has about 140 beds. Many of the patients with tuberculosis came from Greenland, and there were about twenty children. We had a useful discussion, and as usual there was great friendliness and most generous hospitality.

Next, I visited Oslo, being based at the Martina Hansens Hospital about twelve miles outside Oslo. This hospital of 120 beds was built in 1926 for bone and joint tuberculosis. Now about half the beds are occupied by other orthopaedic conditions. Dr J. Hald, the surgeon in charge, and his assistant, Dr J. Sandaa, operate on the tuberculous focus in most cases, being insistent on thorough elimination of all dead and infected material.

While in Oslo I visited the orthopaedic hospital of about ninety beds. Injuries are not treated in this hospital. Dr I. Alvik was unfortunately sick, but I was conducted round the hospital by Dr Foss Hauge and had a most interesting discussion. Dr Alvik employs derotation osteotomy of the femur in a number of cases of spastic conditions as well as in almost all cases of congenital dislocation of the hip. I saw also the Crown Princess Martha Hospital, built since the war mainly for cases of poliomyelitis. Dr Nissen Lee, in charge of this hospital, showed me the wards and the excellent physiotherapy facilities; a large occupational therapy department is being constructed on functional lines.

Then I went to Sweden, first visiting Gothenburg where I had been very kindly invited to stay with Professor E. Moberg. In this hospital, treating injuries of all kinds, Professor Moberg is especially interested in hand surgery, and I had an excellent demonstration of all aspects of assessment, operation and follow-up of these cases. I saw also the new department in the University Hospital, which is being made ready for Professor Moberg in the near future.

I also visited Professor E. Severin at the University Orthopaedic Hospital where all orthopaedic conditions are treated, but no injuries. Professor Severin spoke about anteversion in congenital dislocation of the hip and also explained the workings of the Swedish health service and some of the plans for orthopaedic care in Sweden in the future.

I next went to Lund for the Scandinavian Orthopaedic Association meeting. Professor G. Wiberg had kindly arranged for me to stay at the hospital. I enjoyed the meeting very much and found it possible to follow most papers from the illustrations and a running commentary from helpful friends.

I was invited to visit the orthopaedic department of the hospital at Malmö by Dr S. Von Rosen, who is particularly interested in congenital dislocation of the hip and showed me some children undergoing treatment on his malleable metal frame, and demonstrated clinically and in a film his use of Ortolani's sign for the early detection of subluxation and dislocation of the hip.

I then moved to Stockholm, where the orthopaedic hospital at Karolinska Institutet is under the direction of Professor S. Friberg. Again the patients treated are purely orthopaedic, though some cases of late reconstruction after injury are also dealt with. Dr T. Hiertonn, next senior to Professor Friberg, is particularly interested in vascular surgery and showed some interesting cases and some good results of operation. Undergraduate teaching is carried out at this hospital, and each morning a short clinical conference was held, the students presenting the cases and taking part in the discussion.

While in Stockholm I was able to visit Uppsala, where Professor C. Hirsch has forty adult and children's orthopaedic beds in a general teaching hospital. Professor Hirsch is interested in disc protrusion and I was impressed by his operative exposure in these cases. In addition to attending ward rounds and discussion on many subjects I visited his experimental research laboratory where much original work has been done on intervertebral disc physics and the application of stress to bone.

I visited St Goran's Hospital in Stockholm to meet Dr Mac Fellander, who treats bone and joint tuberculosis in addition to running a busy general orthopaedic and traumatic unit. At this hospital I was introduced to Dr T. Strandell, a general surgeon with a special interest in hand surgery; I watched him operating and saw some of his patients.

I returned to Lund for the last week of my stay in Europe. The orthopaedic department there is part of a large university hospital and deals with casualties from the surrounding area as well as all orthopaedic conditions.

Conclusion

Everywhere I visited, both in England and in other parts of Europe, I met with wonderful hospitality and friendliness. Generally our common language was English, and I felt thoroughly ashamed of my poor efforts at speaking other languages.

During my tour in England, France, Germany, Austria, Italy, Denmark, Norway and Sweden I heard many new ideas propounded, and have seen many new and different methods of treatment. In particular I have been able to compare thoughts on such subjects as tuberculosis of the spine, congenital dislocation of the hip, osteoarthritis of the hip, scoliosis, many aspects of trauma, Perthes' disease, hand surgery, poliomyelitis, paraplegia, the treatment of cerebral palsy, rehabilitation of patients suffering from all kinds of orthopaedic disabilities, and surgical appliances. I am very grateful indeed to the British Orthopaedic Association for making this six-months' tour possible.

ROYAL COLLEGE OF SURGEONS OF ENGLAND

HUNTERIAN ORATION

The Hunterian Oration for 1959 was delivered by Sir Reginald Watson-Jones in the Great Hall of the College on February 16. Sir Reginald took as his title "Surgery is Destined to the Practice of Medicine." After describing the many historical treasures relating to the life and times of John Hunter that are in the possession of the College, he elaborated his main theme that through advances in medicine—both preventive and curative—surgical operations were being rendered unnecessary in an increasing number of diseases. Sir Reginald paid tribute to the work of Lord Webb-Johnson, who had done so much to build up the activities of the College during his Presidency.

JACK COTTON CHAIR IN BIOCHEMISTRY

After the Hunterian Oration it was announced that Mr Jack Cotton, of Marlow, had decided to give to the College a sum of £100,000 to establish a Chair of Biochemistry.

UNIVERSITY OF OXFORD AND OXFORD REGIONAL HOSPITAL BOARD

OPENING OF NEW RESEARCH BUILDING AT THE NUFFIELD ORTHOPAEDIC CENTRE BY HER MAJESTY QUEEN ELIZABETH THE QUEEN MOTHER

On October 27, 1958, Her Majesty Queen Elizabeth the Queen Mother graciously opened the new Research and Teaching Building at the Nuffield Orthopaedic Centre, Oxford.

An otherwise perfect day was marred by the absence, through illness, of Lord Nuffield, whose generous gift of £200,000 had made the project possible. In his absence, Lady Nuffield handed over the Building to Sir George Schuster, the Chairman of the Oxford Regional Hospital Board, who received it on behalf of the Minister of Health. Lady Nuffield was thanked by Sir George Schuster on behalf of the Ministry and by the Vice-Chancellor on behalf of the University of Oxford. The building was then received by the Chairman of the Hospital Management Committee, the Duchess of Marlborough, who invited Her Majesty to open the building. In her address Her Majesty praised

FIG. 1

The entrance hall of the new building, showing a plaque unveiled by Her Majesty Queen Elizabeth the Queen Mother.

the generosity of Lord Nuffield and remarked on this and his many other benefactions which have contributed so much to the advancement of healing. Her Majesty also emphasised the importance of research and clinical effort marching side by side for the benefit not only of patients to-day but of patients in the days to come. With the facilities now available this concerted effort is possible in the

Nuffield Orthopaedic Centre. Her Majesty then opened the building which was dedicated by the Lord Bishop of Oxford, assisted by the Chaplain to the Hospital, the Reverend J. E. Cocke. Her Majesty was conducted round the new building, and Professor J. Trueta explained the particular purposes to which the different sections of the Centre are dedicated. Her Majesty showed great interest in its various departments, particularly in the electron microscope and the opportunity it will afford of opening up new and wider fields of investigation. During this tour postgraduate scholars from several parts of the Commonwealth were presented to Her Majesty. Australia, Canada, Pakistan and South Africa were represented. After this inspection Her Majesty presented the prizes and certificates to members of the nursing staff. In her address Her Majesty commended them on their efforts and the choice of their profession. Such was the interest shown by Her Majesty in the new building that the tour was longer than expected. This delay may account for the minor technical hitch which afforded Professor Trueta the unique privilege of presenting his address of thanks to Her Majesty while she and the whole company were standing.

FIG. 2
Her Majesty Queen Elizabeth the Queen Mother inspecting the Centre with Professor J. Trueta.

After these ceremonies Her Majesty toured wards of the hospital, showing particular and sympathetic interest in the patients suffering from poliomyelitis, speaking with many of them. Her Majesty then took tea in the gymnasium, where she consented to receive many members of the medical and lay staff of the hospital. After a full afternoon's programme Her Majesty left to stay at Blenheim Palace with Her Grace the Duchess of Marlborough. As she was leaving she learned that this great day for the Centre coincided with the birthday of Professor Trueta who, together with Lord Nuffield and the late G. R. Girdlestone, was primarily responsible for its creation. She turned back to congratulate him on his double event and wished him many anniversaries as happy as this one. Her Majesty left behind a multitude of people, patients, visitors and members of the staff, charmed by her graciousness and the warm sincerity of her interest.

This ceremony realises the dream of G. R. Girdlestone that, a comprehensive orthopaedic service having been established in the Region, an Orthopaedic Centre should be created where research, teaching and clinical work should proceed together in most intimate collaboration. It was also his wish that the great generosity of his friend, Lord Nuffield, without which none of these hopes would have been fulfilled, should be commemorated in the title " Nuffield Orthopaedic Centre." Finally, it was the industry and drive of Girdlestone's disciple, Professor Trueta, that crystallised the dreams of one and the generosity of the other in the creation of this Centre.

The new building, consisting of three floors, contains on the ground floor a greatly enlarged records office, a large out-patient department where patients can be received in comfort, and a suite of offices for the consultant staff. On the next floor a greatly enlarged radiological department will now be able to deal with the hospital's work as well as the extra demands of a research centre. This floor also contains a lecture theatre, seating over 150 people, and a dining room and common room for the staff. The top floor houses the Nuffield Department of Orthopaedic Surgery of Oxford University, containing a museum, an enlarged medical library, increased laboratory facilities, a special Medical Research Council department with an electron microscope and x-ray diffraction apparatus, and a suite of offices for the Professor, his assistants and postgraduate scholars.

REGIONAL ORTHOPAEDIC CLUBS

SOUTH-EAST METROPOLITAN REGIONAL ORTHOPAEDIC CLUB

A clinical meeting was held at the Kent and Sussex Hospital, Tunbridge Wells, on November 15, 1958. Patients were shown by *Mr W. H. Gervis* and *Mr E. W. Bintcliffe*.

Excision of the trapezium—*Mr Gervis* showed a thirteen-year result in a farm worker aged sixty-one who had arthritis of the carpo-metacarpal joint. He had remained at his normal work since the operation, and the stability and power of the thumb were little short of the normal. Those present agreed that the operation was certainly not as unsatisfactory as many members had previously thought.

Hallux valgus—*Mr Gervis* showed three patients for whom he had done a Keller's operation, preserving the base of the phalanx to make a wedge-shaped inlay for arthrodesis of the tarso-metatarsal joint, at the same time correcting the metatarsus primus varus deformity. The prominent head of the metatarsal was reshaped and the shortened lateral sesamoid ligament divided.

In discussion *Mr R. H. Sewell* said that Keller's operation left a non-functioning toe. *Mr J. H. Mayer* believed that, since the pain was relieved by Keller's or Mayo's operations, there was no need to fuse the tarso-metatarsal joint. *Mr P. R. Wright* agreed with this. *Mr J. E. Buck* said that in at least one case there was enough permanent disturbance of cutaneous sensation to account for the non-perception of pain, and *Mr R. C. F. Catterall* suggested that the whole foot was so mobile in these cases that splaying was likely to recur elsewhere. *Mr T. T. Stamm* thought that no patient could walk quite normally after such procedures because the muscle balance was impotent to re-establish adductor function. *Mr J. C. F. Lloyd-Williamson* advocated a supporting figure-of-eight strap to help maintain correction after any operation for hallux valgus.

Backache—*Mr Gervis* showed three patients treated by gradual full mobilisation. He ascribed the backache in these patients to lack of movement causing excessive wear of the bearings in one position. He said that animals stretched often and thoroughly whereas man stretched seldom, if at all, and never thoroughly. The patients had all originally had limited extension, and, though no sensory, motor or reflex changes were present, some had referred sciatic pain. *Mr Catterall* disagreed with these ideas and pointed out that in post-partum backache, at least, the cause could not be due to lack of extension because lordosis was increased during pregnancy. *Mr F. G. St C. Strange* suggested that in many cases of this sort the patient could be cured by the injection of pain spots and a treatment which he described as a " laying on of thumbs." *Mr B. Lawson* thought that such treatment caused so much local pain that the patients no longer dared to mention their backache.

Quadricepsplasty—*Mr Bintcliffe* showed a remarkably good result from Campbell's technique. Members could not but admire the result, but few had had the courage to try it themselves.

Difficult supracondylar femoral fracture—*Mr Bintcliffe* sought advice in the case of a man of fifty-one who had suffered a severe compound fracture involving the knee joint eighteen months before; there was still insufficient union for safety out of his caliper and the knee joint was very stiff. It was suggested that the small knee movement could be sacrificed and that a massive inverted tibial graft should be used after the manner of R. Merle d'Aubigné. *Mr Catterall* and *Mr Sewell* called attention to the stiffness of the hip on the same side, and *Mr K. F. Hulbert* recalled a case in which an acetabular fracture had been discovered at an insurance consultation and the three years' correspondence with the Medical Defence Union had only just closed. It was agreed that in any compound fracture of the lower limb occurring in a motor-cycle accident the hips should be radiographed routinely.

Trans-scaphoid perilunar dislocation of the wrist—*Mr Bintcliffe* showed a man of thirty-five who had fallen off a ladder at work a year before. Two months after the injury it was apparent that the scaphoid bone was avascular, and a bone graft was carried out. The patient was still not at work. *Mr Buck* suggested that the man was fit for work and was just not trying. *Mr Bintcliffe* agreed that the patient was " interested in compensation."

Local gigantism—*Mr Bintcliffe* showed a girl of nine months whose index finger, at birth, had been almost as large as the rest of the forearm. The middle finger and thumb were less affected and the ring and little fingers were normal. There was no known family history of any defect for two generations. Mr Bintcliffe had already removed the index finger and sought advice. Suggestions varied between rotating the little finger into opposition and excision of subcutaneous tissue in the thenar eminence, but most of those present were not in favour of further surgery.

SHEFFIELD REGIONAL ORTHOPAEDIC CLUB

The second meeting of the Sheffield Regional Orthopaedic Club was held at the Royal Infirmary, Sheffield, on November 8, 1958, under the chairmanship of Mr F. W. Holdsworth.

During the morning a number of patients were available for examination and later the problems which they presented were discussed. Suggestions were put forward by Mr Holdsworth about the formation of a Regional Bone Tumour Registry which is to be started in the near future at Sheffield.

Giant-cell tumours—*Professor D. H. Collins* emphasised that the pathologist can play only a limited role in the diagnostic team if he is content to pronounce on no more than the histological appearances of a small fragment of tissue; this was especially so in the case of bone tumours. The growth potential of bone cells changed enormously throughout life, and the pathologist must know the age of the patient; he must also know the anatomical site of the lesion; and the clinical radiograph or the radiograph of the bony specimen was as essential in the pathological examination as, say, the naked-eye inspection of a tumour excised from the breast or bowel. Some of the giant-cell lesions of bone were histologically very much alike, yet differed greatly from one another, and the diagnosis of osteoclastoma should not be proffered by the pathologist if the lesion was, for example, in the jaw of a ten-year-old girl, when it was almost certainly a central epulis, or in the clavicle of a fifty-year-old woman, when it might be a manifestation of hyperparathyroidism. The more facts we know about the circumstances as well as about the appearances of each giant-celled lesion, the more accurately could we place it into the appropriate pathological category. This was important not only from the point of view of the individual patient, but also in assessing the efficacy of various recommended modes of treatment. The term osteoclastoma should be restricted to the rather rare primary non-metastasising tumour of bone, arising usually at the extreme ends of the long bones after union of the epiphysis to the shaft, but occasionally also in the bones of the pelvis. Most of these occurred round the knee joint, the growth caused massive osteolysis, and the bone was often resorbed practically to the articular cartilages. It did not occur in childhood and was seldom seen below the age of twenty, and women were as commonly affected as men. Histologically the tumour was compounded of spindle fibroblast-like cells and syncytial multinucleated masses of osteoclast-like giant cells. For all practical purposes the tumour might be regarded as non-metastasising, although individual variations in the vigour of local growth might be reflected in the cellularity and mitotic activity of the spindle cells. So defined, osteoclastoma had a common set of attributes and could be clearly separated from other giant-cell lesions for statistical as well as for prognostic purposes. The supervention of sarcoma in osteoclastoma was a theoretical possibility, as it was in the case of any other characteristically benign tumour. But most giant-cell sarcomas of bone were found to have arisen either from atypical sites or at an atypical age, and might have been potentially sarcomas from the start. Giant-cell sarcoma was a common form of Paget's sarcoma in older patients, and it was wrong to describe this as malignant osteoclastoma. The lesions of osteitis fibrosa might be histologically indistinguishable from osteoclastoma, but the gross characteristics were very different. Giant-celled epulis or central epulis arose usually in children in either mandible or maxilla; there was much debate whether this was tumour or granuloma. Aneurysmal bone cyst was a form of skeletal angioma, and was a primary vascular tumour of bone that passed through phases of growth and stability. In the stable form it resembled a cavernous angioma, but when it was growing osteoclastoma-like tissue was prevalent. Benign chondroblastoma (Codman's tumour) had many distinguishing features, but giant cells were prominent here as they were in the more recently described benign osteoblastoma which might have some relationship with osteoid osteoma. There were, of course, many other lesions of bone in which giant cells might be prominent. The only way of clarifying the situation in regard to giant-cell tumours was to reach a precise diagnosis in every case, and this could best be achieved by conference and agreement between the clinician, the radiologist, and the pathologist.

Congenital paralytic dislocation of the hip—*Mr W. J. W. Sharrard* pointed out that, with improved techniques for the closure of myelo-meningocoele and the control of secondary hydrocephalus, many more children were surviving, with normal mental capacity but with paralytic deformities. Of about 200 children with meningocoele, fifty-seven had paralysis in one or both lower limbs, and in these children fifty-eight dislocations or subluxations of the hip joint were discovered. In twenty-six cases the dislocation was present at the birth. Mr Sharrard considered that the dislocation in these cases was due to the action of strong adductor, flexor and sartorius muscles acting *in utero* in the presence of paralysed gluteal muscles. There was radiographic and other evidence that the hip joint itself was at first normal, and these cases were therefore not true congenital dislocations of the hip, but congenital paralytic dislocations. Five other dislocations and seven subluxations developed gradually during the first eighteen months of life when there was paralysis below the second lumbar segments. This was again due to the action of unopposed adductors and flexors of the hip. These cases required completely different management from ordinary congenital dislocations of the hip. Operative correction of the contractures was needed to reduce the dislocation, and transplantation of the iliopsoas to the greater trochanter and of the sartorius to the outer side of the knee was needed to maintain reduction of the dislocation.

Fractures of the tibia and fibula—*Mr J. W. Dickson* acknowledged the work of Ellis (1958) (Journal of Bone and Joint Surgery, **40–B,** 42, 190), which was based on 567 cases treated at the Royal Infirmary, Sheffield. The best treatment was the simplest that was compatible with restoration of function. The compound comminuted fractures produced by modern traffic and industrial accidents did not lend themselves to internal fixation, and this method has been applied only rarely and in selected cases. Wound excision, reduction (often by traction applied to a Steinmann pin in the calcaneum) and immobilisation in plaster continued to produce good results with an incidence of non-union of less than 3 per cent, and practically no ill-effects upon the calcaneum. Distraction, frequent changes of plaster, and early weight bearing except in transverse stable fractures, must be avoided.

Neonatal sciatic palsy—*Dr N. E. Shaw* reported three patients with neonatal sciatic palsy who were admitted to the Children's Hospital, Sheffield, during 1957. The cases were unusual, because each occurred in twins. The classical features of the condition were present in each case. All the babies were born by caesarian section and suffered from asphyxia pallida at birth, and an injection of Nikethamide (1 millilitre) was administered into the umbilical cord. Shortly afterwards a mottled purplish discoloration was observed over the skin of the left lower limb and buttock, and the skin of the left iliac fossa. A left foot drop was also present. In one case the condition progressed to massive gangrene of the parts supplied by the femoral and internal iliac arteries, and the child died. In a second baby a pericolic abscess developed in addition to the foot drop, and the abscess was drained. This child still had a sciatic palsy, but in other ways had made excellent progress. The third baby had made a complete recovery. Dr Shaw recalled similar cases described by Fahrni and by Mills. McFarland had suggested that the condition might be caused by the injection of Nikethamide into the umbilical artery instead of the umbilical vein, so that the analeptic was distributed through the internal iliac and femoral arterial tree and caused spasm of these vessels. This explanation was certainly in accordance with the clinical findings in the cases presented.

SOUTH-WEST ORTHOPAEDIC CLUB

The Autumn Meeting of the South-West Orthopaedic Club took place on November 29, 1958, at the Princess Elizabeth Orthopaedic Hospital, Exeter. Mr G. Blundell Jones was in the chair. Thirty members were present.

Stress fractures of the neck of the femur—*Mr C. C. Jeffery* (Exeter) reviewed the clinical features of this condition and showed three patients whose femoral necks had been satisfactorily treated by nailing. The shortest period of observation was three years and there was no evidence of avascular necrosis so far. Sound union of the fractures had been achieved in all.

Treatment of the fractured femur by intramedullary nailing—*Mr F. C. Durbin* (Exeter) reviewed forty-two selected cases of fractured femur treated in this manner at Exeter during the last ten years. He presented six cases which would have posed great problems if treated otherwise. Four patients had comminuted simple fractures in which a nail and several encircling wires had been used for fixation. Sound union with good knee movement had been obtained in all. There followed a patient with a transverse fracture of the upper third in Paget's disease with full function, and finally a boy of seven years with a meningocoele in the thoracic spine and paraplegia who had developed multiple fractures in the bones of the lower extremities, a complication previously reported by Katz (1953) (Journal of Bone and Joint Surgery, **35–A,** 220). Fractures of the right femur and tibia had been

treated by intramedullary nailing, the femoral nail transfixing the knee joint. Before operation the boy had been bedridden, and now he was able to walk with calipers and a walking cage. Few complications had been encountered, and all fractures in the series were soundly united and most patients had full range of movement in the knee. Two instruments which could be purchased from any ironmonger cheaply and which were most useful in intramedullary fixation were a Cobra bit $\frac{3}{8}$ inch in diameter and 24 inches long, which made an excellent reamer, and the "Mole" self-adjusting wrench, which enabled a firm grip to be taken on a nail when extraction was necessary.

Problems in scoliosis—*Mr G. Blundell Jones* (Exeter) showed some difficult problems which included infantile scoliosis, kypho-scoliosis with arachnodactyly and paralytic scoliosis. The Risser localiser plaster and a modified form of the Milwaukee brace had been used. Slides were shown of the technique of application of the localiser plaster and the special frame was demonstrated.

Other cases—Members of the staff also demonstrated patients with the following conditions: 1) chondrosarcoma of the pelvis treated by hindquarter amputation; 2) resection of the lowest third of the radius for malignant osteoclastoma and replacement by a fibular graft; 3) arteriovenous aneurysm of the posterior tibial artery involving the tibia and following a simple fracture of the tibia: part of the tibia had been resected and the vessels had been ligated; 4) two cases of recurring sarcoma in the pelvis after disarticulation at the hip for sarcoma of the lower end of the femur; 5) local resection of the proximal half of the humerus for osteogenic sarcoma: there had been a local recurrence which was now receiving radiotherapy.

Bone sarcoma—In a discussion on bone sarcoma *Mr Norman Capener* (Exeter) said that it had been shown in America that the results of conservative resection were no worse than those of amputation. In the case of the upper limb he felt that there was a place for conservative surgery as the use of the hand could be retained. *Mr F. C. Durbin* felt that radiotherapy alone had no place in the treatment of bone sarcoma. It rarely effected a cure or relieved pain, and deformities followed. When the lower extremity was involved amputation assisted the early rehabilitation of the patient. *Mr A. L. Eyre-Brook* (Bristol) did not entirely accept that view. He knew of at least two cases in which a bone sarcoma involving the shoulder region had been cured by radiotherapy. He felt that radiotherapy still had a place where amputation was difficult or unlikely to effect a cure, as in tumours close to the trunk. *Mr Dillwyn Evans* (Cardiff) had seen a patient with an osteogenic sarcoma of the lower limb who had later developed another osteogenic sarcoma in the opposite humerus, indicating that local spread could not have taken place. He believed that if possible a malignant bone tumour should be irradiated with a lethal dose of x-rays and that the limb should then be amputated.

Upper limb anomalies of muscle and nerve—Two patients were shown. The first patient, a boy of nine, had aplasia of muscles and tendons in the arms, forearms and hands. A Clark pectoral transplant had been employed on both sides using a plantaris tendon graft to continue the pectoral tendon to the radius. The transplant worked well but flexion was limited. Before operation passive flexion of the elbow was deficient and had to be regained by serial plasters. *Mr D. M. Rocyn Jones* had had a similar case in which he had used a pectoral transplant and extended it into the radius with a strip of fascia lata, but this had not been satisfactory. The second patient was a girl aged seven with a symmetrical paralysis of all muscles supplied by the eighth cervical and first thoracic nerves, ascribed to injury at birth. Paralysed muscles and tendons had been demonstrated at operation.

Disappearing metatarsal bones—A woman of sixty was presented who had developed fixed clawing of the toes and cavus deformity of both feet during the previous ten years, with ulceration of the metatarsal heads in the soles of both feet. There was no apparent vascular or neurological disorder. Surgical treatment was required to remove the bony prominences: on the right side the metatarsal bones were disarticulated completely, and on the left side the head and half of the shaft of each metatarsal were excised. The patient was now comfortable and able to walk with surgical shoes. Sections of the bone which had been seen by Professor S. L. Baker shed no light on the problem. *Mr Hedley Hall* said that he had encountered a family who had suffered from a similar condition. It had affected first a male and later four male siblings. These four males had later died without issue as they had been sterile. No conclusive views about the pathology had been reached. *Mr J. Bastow* described a similar case, and reference was made to another case described by Mr A. E. Jowett at a previous meeting.

Infantile coxa vara—Three patients were shown in whom the deformity had been corrected by osteotomy. In one patient the fixation had been by Steinmann pins incorporated in a plaster spica. A Capener nail-plate and plaster spica had been employed in two patients. Remoulding of the upper end of the femur had taken place in all the patients, who had excellent function.

Fracture-dislocation of cervical spine with tetraplegia—A man of fifty was presented with a complete tetraplegia below C.7 after a fracture-dislocation of C.7 on T.1. With ordinary radiological technique it was impossible to obtain radiographs that showed the lesion. Tomography showed it clearly and was a valuable means of diagnosis in the very difficult situation.

Medullary nailing of fractures of the shaft of the tibia—*Mr M. Alms* (Bristol) reported the results of fixation of twenty-one closed fractures of the shaft of the tibia with an ordinary large straight femoral nail. Union had been achieved in all cases. Walking without external fixation commenced ten days to three months after operation, depending on the stability of the fracture. Two patients showed delayed union, but the remainder all had union at four months. The average duration of absence from work was ten weeks, and functional recovery was complete, comfortable and rapid.

Arthrography in congenital dislocation of the hip—*Mr S. Tupman* (Bath) believed that arthrography was an essential part of the investigation and planning of treatment in every case of congenital dislocation of the hip. He said that the possibility of redislocation from an obstruction or from dysplasia of the hip could be appreciated only by arthrography. The surgeon could diagnose more accurately, check without doubt his reduction, and serially check the maintenance of reduction and the development of the acetabular roof. Arthrography was a simple procedure with few failures if care were taken to place the point of the needle into the cartilage of the femoral head and to elicit a reciprocal " rocking " sign of the needle on rotation of the leg. The technique was demonstrated by a short film. No complication had been found in over 120 cases. Slides of fifty-four arthrographs representing fifteen cases were shown.

Arthrodesis of the hip by Charnley's method—*Mr J. Piggot* (Exeter) reviewed seventy cases with a follow-up of at least one year, the average follow-up being two years nine months. The operative technique was that described by Charnley, but cheaper simplified instruments were used and a compression screw was not employed. Patients were allowed to bear weight in two weeks. They wore a long spica for about four weeks and a short spica for a further seven weeks. The average stay in hospital was only forty-six days. There was no early post-operative mortality. Bony fusion had been obtained in 74 per cent. A detailed analysis of the results and complications was given. There were 46 per cent excellent results, 24 per cent good results, 17 per cent fair and 13 per cent poor.

Dislocation of acromio-clavicular and sterno-clavicular joints—*Mr K. Pridie* (Bristol) reviewed the methods of treatment of dislocation of the outer and of the inner end of the clavicle and the disadvantages of various forms of treatment. He described his experience of removing the outer, middle and inner ends of the clavicle for 1) ununited fracture, 2) arthritis of the acromio-clavicular joint, 3) sterno-clavicular dislocation, and 4) tumours of the inner end of the clavicle. He showed an ununited fracture of the middle of the left clavicle which had been treated by subperiosteal resection of the false joint and one and a half inches of the middle of the clavicle. A radiograph seven years later showed the clavicle to be indistinguishable from normal. This clearly demonstrated the regenerative powers of the clavicle. Cases of complete outward and backward dislocation of the clavicle which had been treated by excision of the outer two inches were described. Two cases of recurring dislocation of the inner end of the clavicle were demonstrated with photographs taken before and after operation. The advantages of partial excision were a full return to activity, lack of pain and discomfort and excellent cosmetic results as compared with conservative treatment and other operative measures which so often failed. Conservative treatment of acromio-clavicular dislocations was satisfactory only in subluxations and minor dislocations. In complete dislocations a clavicle burst out from its periosteum and could not be replaced. Conservative treatment in such cases was painful and unsatisfactory. Surgical removal of the outermost third of the clavicle gave excellent cosmetic results with a quick return to full function. Within three weeks the patient had full shoulder movement and was able to do strenuous work in six weeks from the date of operation. *Mr Norman Capener* said that the operation of excision of the clavicle was not new and that successful cases in Metropolitan policemen had been demonstrated by Furlong at a meeting of the Orthopaedic Section of the Royal Society of Medicine at Pyrford in 1942.

Observations on Perthes' disease—*Mr G. Blundell Jones* reviewed eighty-three patients with Perthes' disease who had been treated by immobilisation on a Jones's frame and later in a plaster spica, and in the final stages in a weight-relieving caliper. He thought that it might be possible to demonstrate the effect of traction and immobilisation by examining the small group of patients who presented originally without any radiological change. Seven such cases produced four good, two moderate and one poor result. This was no better than the average result in the series. A further group of twenty-six patients who presented without collapse of the head but with increased density of the epiphysis showed a similar distribution of the results. There was nothing in the investigation which supported

the view that traction was necessary in the initial stages of the treatment, but further work was necessary to confirm the findings of Evans and Lloyd-Roberts in 1958 that the simple avoidance of weight bearing was adequate treatment.

Some recent studies in spondylolisthesis—*Mr Norman Capener* said that the basic lesion of spondylolysis occurred in infancy and he suggested that trauma played a part probably in initiating a fatigue fracture in material that was defective for developmental or other reasons. The displacement of spondylolisthesis occurred in adolescence. Reduction could be effected by extending the spine with traction. In the development of spondylolisthesis a kyphosis was formed at the site of the slipping. The deformity could be corrected only by changing the kyphosis into a lordosis, which in fact required extension of the spine. It was extremely difficult to maintain the corrected position by grafting. He doubted whether heroic measures were necessary and in most instances the spine stabilised itself by developing a buttress of bone below the displaced vertebra. *Mr E. Mervyn Evans* showed radiographs of a man who had been injured in a road accident and had fractured a femur. The development of serious bedsores in the sacral area and loss of control of the bladder drew attention to a cauda equina syndrome. Radiographs revealed a complete forward displacement of the fifth lumbar vertebra on the first sacral. The bedsores prevented an effective reduction.

BOARDING SCHOOL FOR THE EDUCATION AND REHABILITATION OF PHYSICALLY DISABLED BOYS

Another step in combining the education and rehabilitation of boys suffering from paraplegia, poliomyelitis, or other serious physical disabilities has been taken by the establishment of Hephaistos School, Farley Castle, near Reading. It will be an independent boarding school with at no time more than forty-five pupils who will be admitted from the age of five years and will be able to stay until normal school leaving age with education up to the G.C.E. Advanced level. The intention is that boys with severe physical disabilities who are not educationally sub-normal should be given the greatest opportunity of a high standard of education despite their handicap. It is a non-profit-making school established by Mr David Atterbury, whose tank was blown up by a land mine in the last war, in consequence of which he himself has traumatic paraplegia from a vertebral injury.

SOUTH AFRICA

SOUTH AFRICAN ORTHOPAEDIC ASSOCIATION: SEVENTH CONGRESS, 1958

The Seventh Congress of the South African Orthopaedic Association was held in Johannesburg on October 23–25, 1958. Mr A. J. Helfet presided, and distinguished guests from abroad included Dr J. E. M. Thomson (Lincoln, Nebraska) and Miss Maud Forrester-Brown (Edinburgh).

The lumbar spine in the Bantu—*Dr L. M. Jonck* (Pretoria) had examined 748 Bantu spines, in the living under conditions of vertical loading, and in the cadaver by macroscopic and microscopic dissection. The anatomical features contradicted most of those described in current anatomy text-books: thus 1) The supraspinous ligament, strong in the thoracic spine, was totally absent in the lumbar. 2) The interspinous ligament, peculiar to man, was made up of fibres whose direction was essentially from lamina below to inferior surface of spinous process above. 3) The interspinous ligament, ligamentum flavum and fibrillar lamellae of the annulus fibrosus together formed a ligamentous triad which guided the movements of the vertebra above upon the one below. He likened the movements to a rocking horse action, which was guided and assisted by the nucleus pulposus. 4) The erector spinae muscle was a powerful force, the two components of which were in a horizontal (dorsal) and vertical (caudal) direction. The dorsal component was resisted by the interspinous and annulus fibrosus fibres, degeneration or destruction of which led to " reversed " spondylolisthesis. 5) Reversed spondylolisthesis plus disc space narrowing led to compression of the nerve root in its foramen, between the inferior surface of the pedicle above and the apex of the superior articular facet of the vertebra below. Gradual compression of the nerve root, which at that level was clothed in its axillary fold of the dural sac, permitted the nerve root to " carve " a niche for itself in the vertebral body, after the same fashion as an aneurysm of the aorta. Sudden compression gave rise to acute sciatic pain. 6) Vertical loading of the spine increased the sacral angle. While this more horizontal position

of the sacrum did bring about an increased shearing strain at the lumbo-sacral disc (load × sine of sacral angle), it had the effect of increasing the length of the lever (in this case the dorsum of the sacrum) upon which the erector spinae muscles acted. The mechanical advantage of the latter was therefore improved two or three times. 7) None of 200 adult Bantu men who for from twenty days to twenty years had shifted a total of twenty-five tons of meal over a distance of seventy yards a day, had suffered a " disc syndrome " or lumbar osteoarthritis.

Mr G. F. Dommisse (Pretoria) said that he had been privileged to examine many of Dr Jonck's anatomical specimens, and to confirm much of what he had postulated. He felt sure that many hitherto inexplicable features in the treatment of the painful back would be clarified on the basis of these findings, not the least of which was the prolonged disability that followed even the simplest of disc removals. Stripping of the multifidus muscle fibres from a large number of spinous processes was undoubtedly a harmful procedure; recovery was probably never complete. *Dr J. E. M. Thomson* (Lincoln, Nebraska) had been impressed by tears of the supraspinous ligament in the lumbar region that could be demonstrated at operation, and he had difficulty in believing that no supraspinous ligament existed. *Dr Jonck* replied that slips of origin of the lumbo-dorsal fascia from the tips of the lumbar spinous processes were commonly mistaken for fibres of the supraspinous ligament. With regard to the operation for laminectomy and disc removal, he was at present investigating a most promising approach, slightly lateral to the standard approach, which could be made through bloodless anatomical planes.

Prosthetic replacement of the femoral head for recent fracture—*Dr J. E. M. Thomson* (Lincoln, Nebraska) reviewed the history of the treatment of these fractures, and paid tribute to the late Fred Albee whose bone-grafting procedure was, in his opinion, the first constructive advance. To-day, and since 1949, he himself favoured the Austin Moore endoprosthesis which, in his clinic, had been inserted in ninety-four patients, the average age of whom was seventy-nine years. He considered the method to be unsuitable for individuals less than sixty-five years old. Results in his series compared closely with those of a series of 163 cases reported by the Committee on Trauma of the American Orthopaedic Association: 39 per cent were graded as excellent and the same percentage as poor; but of the patients with "poor" results many were enjoying a comfortable wheel-chair existence. This, considering their ages, was not unsatisfactory, and he was in any case much opposed to early weight bearing after the operation. Thirty-two of his ninety-four patients died within twelve months of operation, a more or less natural mortality rate in this particular age group. The unsatisfactory experience with the Judet type of prosthesis was reflected in its steadily diminishing sales in the United States since 1951.

Mr F. P. Fouché (Johannesburg) recalled his experiences in the use of the Smith-Petersen nail since 1935. He performed an open reduction, and transfixed the head securely by inserting the nail up to and into the hard subchondral layer of bone; unless this was done, the softness of the remaining portions of the head in old people was sure to cause failure. This was a procedure of some magnitude, and those who were considered too frail were encouraged to get up and bear weight as soon as possible. This allowed the fragments to shift and unite in the displaced position, and it prevented the development of a fixed mental pain-pattern which had proved most intractable.

Normal variations of bone in radiological diagnosis—*Dr M. Denny* (Johannesburg) read a paper which *Professor E. Samuel* (Edinburgh, late of Johannesburg) had prepared. Confusion was common, and many innocent " lesions " were interpreted in a serious and entirely faulty light, for example: 1) fibrous rests and cartilage rests in bone, disappearing with normal growth; 2) epiphysial variations, mistaken for osteochondritis dissecans at the lower femoral epiphysis, for apophysitis at the calcaneum (Sever's disease), for osteochondroma or chronic osteitis at the ischio-pubic region, for fractures at the tip of a spinous process or at the tuberosity of the navicular bone; 3) exaggeration of normal muscular ridges, variations in normal bone architecture as at the lower part of the femoral neck, enlargement of intervertebral foramina or of foramina of the skull, mistaken for secondary carcinoma, neurofibromatosis and the like; 4) variations in normal healthy callus; these could be differentiated from sarcoma by means of arteriographs. *Mr J. M. Edelstein* (Johannesburg) stressed the difficulties of diagnosis of these variations from the normal, and warned that a " fibrous cell rest " could prove to be the forerunner of a non-osteogenic fibroma. Close observation and long term follow-up examination were of the utmost importance. Osgood-Schlatter's disease was not an osteochondritis at all, but rather a lesion of a ligamentous attachment to bone. Apophysitis of the calcaneum should be regarded as a disease process, when associated with local pain, tenderness and swelling; the diagnosis was not to be made on radiological grounds alone.

Repair of the lateral ligament of the ankle—*Mr R. Hamilton Bell* (Cape Town) had performed twenty operations for reconstruction of the lateral ligament of the ankle in cases of chronic lesions. A free fascial graft was used, and it was threaded through drill holes in fibula, talus (and, when necessary,

calcaneum) as in the Watson-Jones technique with the peroneus longus or brevis tendon. Results were universally good. The fascial transplant actually increased in strength and dimensions with the passage of time, and caused permanent diminution of ankle movements if pulled too tight when inserted.

The sprained ankle—*Mr N. Mungo Thompson* (Pietermaritzburg) discussed the acute case, and described a new test for the torn lateral ligament: the inversion test was difficult of application, but the anterior drawer test was easy; it required no local or general anaesthetic and it was reliable: if the lateral ligament was torn, the talus could readily be displaced forward within its mortise. Early surgical repair was both essential and effective in these cases. *Mr J. F. P. Mullins* (Durban) called attention to the distal tibio-fibular syndesmosis, avulsion of which could so readily be confused with tears of the lateral ligament. Fixation with a screw was essential to recovery. *Mr J. G. du Toit* (Pretoria) agreed with Mr Mullins, but warned that a bi-malleolar screw should always be removed. Weight bearing upon this screw would lead either to toggle motion or to fracture of the screw.

Vascular surgery in trauma—*Mr A. M. Glen* (Pretoria) stated that amputations in association with main arterial trunk lesions had been reduced to 7 per cent by a team of vascular surgeons in Korea, as opposed to 62 per cent in World Wars I and II when treatment had been by ligation. The value of repair and grafting in these cases could no longer be doubted. Recognition of arterial damage was often difficult, and an absent or palpable pulse should not be accepted at its face value. Detailed examination was vital, because ischaemia lasting no more than three or four hours would cause permanent damage to tissues. He wished to debunk a number of " historic precepts " in the handling of these cases. The part should not be heated, nor should it be cooled—either of these manoeuvres could prove disastrous. Nor should it be elevated, as this could embarrass a vital trickle along a blood vessel to the point of actual cessation. Operation should be carried out as soon as possible, and the blood pressure of the patient restored in order to promote collateral circulation in the affected part. End-to-end suture was the procedure of choice, but autogenous grafting, using the saphenous vein, with or without a by-pass graft was done if there was intimal damage necessitating resection. Homografts were used when autogenous grafting was impracticable; synthetic replacements had little if any place in the presence of open, potentially infected wounds. Thrombosis in the injured vessel or in the graft was a common cause of failure, and required repeat operations in which a satisfying percentage of successes had been achieved.

Dr M. Berk (Johannesburg) said that arteriography was valuable in cases of trauma, yet it was not receiving the attention it deserved. He showed the arteriographs of five cases in which vital information was obtained which was unobtainable from any other source; not only had the level of the lesion been determined, but also the type of lesion, the presence of anatomical variations, etc.

Mr P. Theron (Johannesburg) agreed with the two previous speakers. Arterial spasm was a common complication in cases of trauma, and even arteriographs were difficult to interpret in these cases. Papaverine pledgets packed round the spastic artery for about ten minutes, or alternatively hyalase plus procaine infiltration of the arterial wall, were both promising. Anticoagulants were not only valueless, but they could be dangerous and should therefore be entirely excluded. Retrograde catheterisation of the spastic artery was another method which was promising. *Mr W. T. Ross* (Johannesburg) recounted his experience, reported in the *Journal of Bone and Joint Surgery* (November 1951), in which he had partly severed the popliteal artery while performing a meniscectomy. He merely turned the patient over, exposed and sutured the vessel and watched the uninterrupted return of the circulation in the foot. He did not wish to claim any credit for this good result. *Professor B. J. du Plessis* (Department of Surgery, Witwatersrand University) endorsed the views of the previous speakers and differentiated between neurogenic spasm of the arterial wall which was evanescent and easy to treat successfully, and myogenic spasm which was not. He repeated the importance of operative exposure of the vessel in the latter, and agreed that the skill of the vascular surgeon was often put to the acid test in these cases.

The role of plastic surgery in orthopaedics—*Mr J. M. Cuthbert* (Johannesburg) outlined the methods of skin closure available, but wished rather to emphasise two more general points: the timing of plastic procedures in the presence of compound fractures, and the integration of the plastic with the orthopaedic services in cases of trauma. Timing was the most important aspect, and he had no doubt that immediate closure of compound wounds was often not desirable. Primary closure in the presence of oedema of soft tissues which had not yet reached its zenith could cause rather than prevent further breakdown. A delay of some days, both in cases with and without skin loss, gave the opportunity of creating conditions in the wound that would make a " take " certain. Too great a delay in applying a graft resulted in advancing epithelialising wound edges and contraction of granulations, both of which required wide excision. Integration of services had hitherto been to a large extent inadequate. To-day it was recognised that a skin flap plus a tendon graft or even bone chip graft could, and indeed should, be done at the same operation on many occasions.

Amputation of the thumb—*Mr P. A. Hugo* (Pretoria) recalled a method of reconstruction described by Sir Harold Gillies, the " cocked hat " advancement of the skin of the thenar eminence combined with a bone peg in the metacarpal head. The defect so created in the palm or on the dorsum of the hand was covered by a Thiersch graft, and the thumb cleft was deepened by a Z-plasty at a later date if needed. Mr Hugo showed a patient in whom this procedure had been adopted, and the outstanding features were the retention of normal sensations over the pulp and the strong grasp between thumb and index finger. The same principle could be applied in the case of amputation of other digits.

Discussion of these two papers was lively, and, in reply to questions, Mr Cuthbert said he would not hesitate to leave a tibial subcutaneous surface uncovered for a few days, during which he would dress the raw surface with " tulle gras " followed by eusol to promote granulations. Relaxing skin incisions with the production of long flaps were not only undesirable but also positively dangerous, because of the advancing oedema in cases of major trauma.

Bone tuberculosis—*Mr C. J. Kaplan* (Durban) compared two series of Bantu patients treated by conservative methods in Durban before and after the advent of antibiotics and chemotherapy. Outstanding results were achieved in the latter series, and the duration in hospital was considerably reduced. Mr Kaplan showed an excellent colour film which portrayed the regime he had adopted. This paper will be published in full elsewhere.

Insert grafts for non-union—*Mr J. M. Edelstein* (Johannesburg) described his experiences in the use of E. A. Nicoll's (1956) (Journal of Bone and Joint Surgery, **38–B,** 70) operation for bridging defects in long bones. The method was of great value, and he presented six patients in whom either the tibia or the radius was involved. Autogenous iliac bone was used in all cases, and a metal plate with two screws at each end provided internal fixation. Bone chips were packed about the graft, which fitted tightly into the space between the bone ends. Five out of six fractures united, and a feature was the prolonged interval between the date of grafting and that of observing radiological evidence of " creeping substitution " of the graft. Mr Edelstein believed that, although this delay might be more apparent than real, it might signify the persistent viability of the bone graft.

Congenital hallux valgus—*Mr C. T. Möller* showed three patients, two of them twins, in whom the Lapidus procedure with slight modifications had been performed eight years earlier. Three of the twins' four feet were graded " excellent " ; the fourth developed a severe recurrence of the deformity. What was the factor which had caused this relapse, and what other procedure should he have adopted? *Miss M. Forrester-Brown* (Edinburgh) suggested an oblique osteotomy of the first metatarsal shaft, followed by a light plaster shell which permitted the shaft to shorten and thereby eliminate the deforming bow-string action of the tendon of the extensor hallucis longus. *Mr R. H. Bell* (Cape Town) performed the osteotomy in the cuneiform rather than the first metatarsal base, and so avoided epiphysial trauma which he regarded as responsible for relapses. *Mr G. T. du Toit* (Johannesburg) avoided any form of bone disturbance in children, and merely diverted the course of the tendon of extensor hallucis longus to a position medial to the metatarsal head. A sling was constructed from the capsule, and it held the tendon in its new position, at the same time permitting its normal amplitude of movement.

Fractures of femoral head—*Mr F. J. Hedden* (Durban) and *Mr R. C. J. Hill* (Durban) reviewed their results in 172 patients operated upon during five years to December 1957. The average age was seventy-one years and the mortality 15·7 per cent. Serious local complications occurred in twenty-four patients of the ninety-one with subcapital and transcervical fractures: avascular necrosis accounted for seven of them. The fracture-angle in the latter group was of no prognostic significance, but the magnitude of the force which produced the fracture was. Severely displaced fractures indicated severe trauma (which included soft tissues) and these were associated with the worst prognosis; these were also the cases in which they now advised primary prosthetic replacement of the head. Trochanteric fractures in which stable reduction was possible were fixed with a McLaughlin type internal splint. Unstable fractures were also operated upon, and the shaft was displaced inwards and upwards as for the McMurray type of osteotomy. It was often necessary to rotate the shaft laterally in order to gain this displacement; a blade-plate was then applied in this position of lateral rotation.

Slipped upper femoral epiphysis—*Mr M. Lunz* (Johannesburg) had performed the Heyman (Cleveland) procedure of removal of the mass of redundant cartilaginous tissue on the superior aspect of the epiphysial cartilage and the metaphysis of the neck. No effort was made to reduce the slipped epiphysis. After ten weeks the result was encouraging. *Mr C. Morris* (Johannesburg) performed an osteotomy through the femoral neck, locked the fragments in position by medial rotation, abduction and extension of the hip, and applied a plaster in this position. He was satisfied with his results, and had not observed necrosis in the femoral heads in his series.

The mechanism of internal derangement of the knee—*Mr A. J. Helfet* (Cape Town) had been able to demonstrate in the quick and the dead the function of the cruciate ligaments and semilunar cartilages in the rotator mechanism of the knee, and the manner in which tears of the cartilages were produced. Unobstructed lateral rotation of the tibia upon the femur was essential to the mechanism of locking; when this rotation was prevented, the anterior horn of the medial cartilage was ground down upon the tibia by the medial condyle of the femur, and one type of cartilage lesion produced. Another type of cartilage tear, commonly known as the " bucket-handle lesion," should rather be referred to as a " bow-string tear," for the rotating medial femoral condyle could and did push the anterior horn of the cartilage forward and laterally, and so caused it to tear in its longitudinal axis and bow-string in part or *in toto*. The pattern of erosion of the medial femoral condyle or the small inner segment of the articulating surface of the patella in association with medial cartilage lesions could now be explained, and could successfully be treated by removal of the damaged cartilage. This paper is published in full in this issue,

INDIA

ASSOCIATION OF SURGEONS OF INDIA: ORTHOPAEDIC SECTION

A meeting of the Orthopaedic Section of the Association of Surgeons of India was held at the Andhra Medical College, Vishakhapattanam, on December 29–30, 1958.

Recurrent dislocation of the shoulder—*Dr A. K. Mukherjee* (Calcutta) reviewed fifty-two cases. He emphasised the importance of congenital factors in the causation of recurrence and recommended the Putti-Platt type of repair as the operation of choice. *Dr K. T. Dholakia* (Bombay) believed that unsuitable treatment of simple traumatic dislocation of the shoulder might predispose to habitual dislocation. He preferred the Bankart type of repair whenever it was possible.

Osteoclastoma—A symposium on osteoclastoma brought out the following points: 1) it is a much commoner tumour in India than in western countries; 2) primary malignant osteoclastoma is a definite pathological entity, whose diagnosis depends on careful histological study; 3) needle biopsy gives a negative result in nearly 50 per cent of benign osteoclastoma and in 100 per cent of malignant osteoclastoma; 4) excision is to be preferred to radiotherapy for all accessible tumours; 5) simple curettage has a higher recurrence rate than total excision; 6) massive excision in the region of the knee can be followed by successful arthrodesis of the knee by sliding bone graft.

Radiological observations on the relationship of the lower humeral epiphysis with its shaft—*Dr D. P. Ghosh* (Asansol) showed radiographs of the elbow taken in strictly lateral position in which two-thirds of the lower humeral epiphysis lay in front of a line drawn along the anterior border of the shaft of the humerus in normal children. This finding was contrary to the statement of Sir Reginald Watson-Jones that such a finding indicates traumatic anterior displacement of the epiphysis. The diagnosis of such displacement depended on clinical findings and not on the radiographs.

Observations on articular cartilage damage—*Dr B. Mukopadhaya* (Patna) reported a series of animal experiments in which he showed that the nature of repair of the articular cartilage of a joint depends to some extent on the type of injury. When the articular cartilage alone was damaged, the repair was very satisfactory. But when a fracture was also present the repair was not so good. He also showed interesting changes in the articular cartilage of the opposite articular surface.

Tibialis posterior transfer for paralytic drop foot—*Dr Selvi Pandian* (Vellore) reviewed cases of paralysis of the lateral popliteal nerve from leprosy in which a transfer of the tibialis posterior tendon was done to the front of the foot either by passing the tendon through the interosseous membrane or by routing the tendon across the medial side of the tibia. The results were good both functionally and cosmetically in nearly 80 per cent of cases. The results from transfer on the medial side of the leg were slightly better than from transfer through the interosseous membrane.

Conservative treatment of trochanteric fractures of the femur—*Dr B. B. Orhi* (Indore) reviewed fifty-two cases of trochanteric fractures of all degrees of severity treated conservatively by traction. The results were satisfactory both anatomically and functionally in fifty of the cases, the oldest patient being 100 years of age.

ANNOUNCEMENTS

BRITISH ORTHOPAEDIC ASSOCIATION TRAVELLING SCHOLARSHIPS

The British Orthopaedic Association invites applications from its Fellows, Members and Associates for two Travelling Scholarships in orthopaedics of about three months' duration to visit centres in Great Britain and/or other European countries. The sum available to each scholar will be not less than £500.

Candidates should apply to the Honorary Secretary, British Orthopaedic Association, 47 Lincoln's Inn Fields, London, W.C.2, setting out the object of the proposed visit, the proposed itinerary, and previous clinical experience and contributions to research, and should give the names of two referees, who must be Fellows of the Association. Twenty copies of the application should be supplied. The closing date for receipt of applications is May 31, 1959.

BRITISH ORTHOPAEDIC ASSOCIATION AUTUMN MEETING, 1959

The Autumn Meeting of the British Orthopaedic Association will be held in London from October 22 to 24, 1959. Those wishing to present a paper at the meeting should submit an abstract of about 400 words to the Honorary Secretary, British Orthopaedic Association, 47 Lincoln's Inn Fields, London, W.C.2, before July 22 at the latest.

THE BRITISH COUNCIL

COURSE IN ORTHOPAEDIC SURGERY

An advanced two-week course in orthopaedic surgery has been organised by the British Council for twenty overseas orthopaedic surgeons with at least three years' experience in the speciality. This course starts in London on June 28, 1959. The programme has been arranged with the help of the Institute of Orthopaedics and is under the direction of Mr K. I. Nissen, of the Royal National Orthopaedic Hospital. Lectures and demonstrations will take place at hospitals in and around London, and a week-end will be spent in Cambridge. Further particulars may be obtained from the British Council, 65 Davies Street, London, W.1.

Book Reviews

TUMORS AND TUMOROUS CONDITIONS OF THE BONES AND JOINTS. By Henry L. JAFFE, M.D., Director of Laboratories and Pathologist, Hospital for Joint Diseases, New York, N.Y.; Consultant, Armed Forces Institute of Pathology, Washington, D.C. $10\frac{1}{2} \times 7\frac{1}{2}$ in. Pp. 629, with 701 illustrations and 194 figures. Index. 1958. London: Henry Kimpton. Price £6, 15s.

This is an altogether admirable account of bone tumours, and may be expected to be the standard work on the subject for many years to come. It contains a wealth of interesting and well documented material: despite this it is a compact and very readable volume.

Dr Jaffe is Director of Laboratories and Pathologist at the Hospital for Joint Diseases in New York, and, with various colleagues from his department, he has been responsible for many papers of outstanding importance on the pathology of bone tumours and related topics; readers of this journal are probably well aware of his work in this field, and of the numerous entities, such as osteoid osteoma, benign chondroblastoma and chondromyxoid fibroma, whose recognition we owe to him. But his original papers on bone tumours are scattered in a variety of medical journals over a period of many years, and it is not easy for most people to consult them: the present volume will bring to a wide audience a detailed, accurate and up-to-date account of his views on all types of bone and joint tumours. It is not a rehash of the original papers, but a systematic account of the whole subject incorporating a number of extensions of his previously published views.

Although Dr Jaffe is a pathologist, the book does not deal only with morbid anatomy and histopathology. Clinical and radiological findings pertaining to the various lesions are presented, and considerable emphasis is given to the correlation and integration of data from the three disciplines, both in defining the conditions concerned and in making individual diagnoses. Dr Jaffe stresses the need for the individual diagnostician—whether surgeon, radiologist or pathologist—to achieve, himself, this synthesis of approach: the book itself is a most outstanding demonstration of the high degree of synthesis that one man can, in fact, achieve.

Each of the main types of bone tumour is represented by a chapter, and in each chapter a standard treatment is adopted. First there is a section dealing with definition and nomenclature; then information is given on incidence, including age and sex incidence. Next come sections dealing with localisation in the skeleton, clinical presentation and radiological findings, followed by a detailed account of gross and microscopic pathology and a discussion of differential diagnosis. The overall emphasis of the book is, of course, on diagnosis, but each chapter is concluded with a brief section on treatment. The illustrations, which are outstanding, show the range of radiological appearances to be encountered in the condition under discussion, as well as features of gross and microscopic pathology. The illustrations are arranged and described so that the various preparations from an individual case—perhaps the radiograph, a photograph of the specimen, and photomicrographs—can readily be compared. With their descriptive legends, the illustrations virtually form an atlas of bone tumours.

One interesting point on which the book throws some light is Dr Jaffe's attitude to tumour classification in general. He thinks there is little to be gained by grouping together various types of bone tumour according to their supposed tissues of origin: he prefers to consider each type of lesion "as a clinicopathologic entity in its own right." It is possible that this approach leads him to give relatively little emphasis to those tumours which appear to "break the rules" and to possess histological features of more than one tumour type: at the same time it is just this approach that has led to such outstanding success in the delineation of criteria for all our important diagnostic groups.

The book will certainly help to raise the standard of diagnosis and treatment of bone and joint tumours wherever it is read. Whenever an interesting or unusual bone tumour is discussed, whether in the wards or the laboratories, a very pertinent question is now going to be "What does 'Jaffe' have to say about this type of lesion?"—H. A. SISSONS.

ORTHOPAEDIC DISEASES. PHYSIOLOGY—PATHOLOGY—RADIOLOGY. By Ernest AEGERTER, M.D., Professor of Pathology and Director of the Department of Pathology, Temple University Medical Center and School of Medicine; Professor of Orthopaedic Pathology, University of Pennsylvania Graduate School of Medicine; and John A. KIRKPATRICK, Jun., M.D., Radiologist, St Christopher's Hospital for Children; Assistant Professor of Radiology, Temple University Medical Center. 10×7½ in. Pp. xii+602, with 354 figures. Index. 1958. Philadelphia and London: W. B. Saunders Company. 87s. 6d.

This is one of the best, most helpful and most interesting orthopaedic books I have ever read. The authors, a pathologist and a radiologist, have aimed at reviewing almost all the known skeletal disorders, describing and correlating their pathology, clinical features, radiology and prognosis. In fact, this is what we have been waiting for: a study of the natural history of orthopaedic diseases. Modestly (and quite incorrectly) disclaiming originality, they describe the book as "a starter." It's a superb start.

The first six chapters form an introduction dealing with the anatomy and physiology of bone, especially as revealed by such modern techniques as the electron microscope and phase-microscopy. The rest, a total of twenty-two chapters, falls into sections dealing with disturbances in skeletal development and disturbances in the normally formed skeleton, and with tumours and tumour-like processes. In each group, indeed in each disease, discussion is critical and practical, based essentially upon the observed behaviour of the disorder in question. Speculation is discouraged: " the application of presumption dressed in the garb of fact." Everything is questioned, even the assumption that a

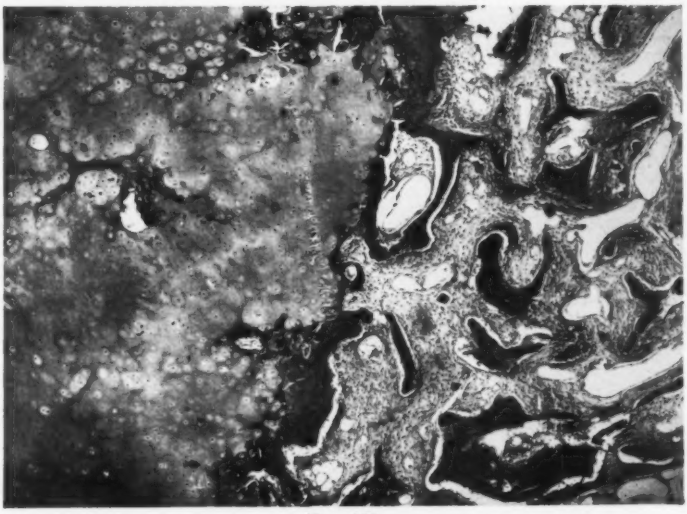

FIG. 103
Fibrous dysplasia. The section reveals a portion of an island of cartilage on the left and fibrous dysplasia on the right. (×35.)

disease is congenital if it has not been observed in the new-born. Animal studies receive no more than their proper importance. Bone healing in the dog and the cat being " little more alike than their temperaments," conclusions drawn from them are not necessarily applied to the human. Of course, a few heresies have survived the authors' razor; the association of hyperaemia with " decalcification," and especially the reverse (page 43), is not a causal relationship, and one feels that the term " diffuse halisteresis " (page 190) is unjustifiable to-day. It is also odd to find post-traumatic osteoporosis accepted as " secondary to alterations in blood supply due to nerve impulse changes "; and is vitamin-D deficiency common " particularly among politically oppressed groups "?

The classification of some of the diseases studied will arouse surprise, though a critic will usually be disarmed by good and logical reasoning in support of the authors' ideas. I doubt, however, if the inclusion of pigmented villonodular synovitis among the infectious diseases of bone is really justified; and is there evidence quite good enough to put non-osteogenic fibroma and unicameral bone cyst among the circulatory disturbances? Why not have a section on lesions which cannot yet be classified? These criticisms are, however, minor and perhaps carping.

Particular praise should go to the chapters on parathyroid disorders. The account of ischaemia of bone is excellent. I suppose most of us will look most closely at the section on tumours. This is first rate. Of course, there is a new classification, for " the only perfect classification is that one constructed by its author." The term " osteogenic " has to be retained for a group of tumours, but your reviewer will not be alone in welcoming the dropping of the term " osteogenic sarcoma." Tumours, as these authors insist, must be classified according to their behaviour and not solely upon their morphology. " Any classification of a disease which is not concerned with the manner and extent to which the patient is affected is tedious pedantry," and so the term " osteosarcoma " is used to include some tumours of bone which differ from osteogenic sarcoma only in that the cells are not seen to produce osteoid. The concept of " osteoclastoma " as a disease-entity receives commendably short shrift, the authors stressing the near impossibility of distinguishing histologically such very different lesions as the giant-cell tumour and the " brown tumour " of hyperparathyroidism. " Ewing's tumour " is retained, to the regret of your reviewer, who must consider himself on the side of the " few distraught writers " who cannot distinguish this " tumour " from metastatic lesions or from reticulum-cell sarcoma.

There are minor defects which will certainly disappear in later editions. Many page references in the introductory section are inaccurate. Pott was not knighted, nor did he describe spinal tuberculosis. Tuberculosis sicca, if it exists at all, is sicca, not sica (dry, not a dagger). A few of the illustrations could be improved. One, purporting to show the deformity of osteomalacia, is surely a radiograph of an old idiopathic scoliosis with, perhaps, an added osteomalacia. The authors apologise for imperfect section-cutting in some of their histological illustrations. Of course, bone sections without folds in them are very difficult indeed to prepare. The format and the publication are admirable. I detected no more than three misprints (caption to Fig. 61; page 81, line 27; and page 293, line 16).

I thoroughly enjoyed reading this book. The style is straightforward and interesting; the presentation is clear and forceful. It is one of the most important books of recent years. If it does not become a classic, so much the worse for orthopaedic readers. I shall find it a constant source of reference and of pleasure. Its authors have every reason to be proud of their achievement.—D. Ll. GRIFFITHS.

FRATTURE E LUSSAZIONI. By L. GUI, Primario incaricato della Sezione di Ortopedia e Traumatologia dell'Ospedale Civile di Faenza; Aiuto Volontario dell'Istituto Ortopedico Toscano di Firenze. $10\frac{3}{4} \times 7\frac{3}{4}$ in. Vol. I—Pp. vii+781, with 902 figures, many in colour. Index. Vol. II—Pp. vi+1,110, with 1,316 figures, many in colour. Index. 1956 and 1957. Firenze: Edizioni Scientifiche Istituto Ortopedico Toscano. Price $78.00.

Here are two magnificent volumes, the best yet produced on the Continent, which owe a great deal to the inspiration of Watson-Jones and include several illustrations copied from him. If published in English they might well tear a leaf or two from the laurel crown so long worn by that author. In style they are a combination of Watson-Jones and Böhler—Watson-Jones in systematisation, well designed illustration and colour but not in literary merit—Böhler in thoroughness, sequential black and white illustration, and the appeal to the over-anxious of the Böhler questionnaire. This time it comes in the guise of a list of errors terminating the description of each fracture. They tend to be a little repetitive, and, seeing the excellent review of first principles in Volume I, it seems hardly necessary to include such errors as " not to examine the unfortunate victim completely," " to fail to institute immediate treatment for shock, haemorrhage and pain," and " not to apply a local and general antibiotic in a sufficient quantity."

Of the two volumes, the first is inevitably the more appealing to the reviewer and less so to the critic, because general principles admit little divergence of view. The volumes are beautifully set out with abundant illustrations, clear and to the point. Anaesthetics, plastic surgery, radiology, rehabilitation, plaster technique, instrumentation and traumatic aneurysms, are all included. Nothing escapes, from the mechanics of the fracture to those of artificial limbs. A few points strike one—bones (and large ones at that) are shown sutured on one side with catgut or kangaroo tendon for stabilisation. I am less worried about the fate of the kangaroos than the fate of the graft, for which this fixation would appear inadequate, and plaited stainless steel wire appears an adequate substitute. In the discussion of gas gangrene, the value of amputation through the joint to avoid wide exposure of muscle is not mentioned, nor is local removal of an affected muscle group in the early stages recommended. The dosage of penicillin advised is quite inadequate. While the advantages of the Küntscher nail as the most effective method of fixing the femur is recognised, the use of screws in spiral and oblique fractures of any kind is omitted.

In the second volume more controversial material appears. The systematic handling of each fracture under headings, while admirably clear, encourages repetition and spoils any flow of thought. The desire to achieve ordered completeness has perhaps overcome the author's judgment. It is impossible to discuss fractures of the skull in the detail attempted for other fractures without overloading the volume. Fractures of the thoracic spine are treated in plaster: no loophole is left for the active treatment of the minor case without it. Fractures of the transverse processes are described without reference to retroperitoneal haematomas; and the complications and treatment occupy three lines which, contrary to the general arrangement, are many pages farther on and extremely difficult to find because unrecorded in the index. Incidentally, a plaster cast for a month is recommended. In acromio-clavicular dislocation the ineffectiveness of acromio-clavicular splintage is well illustrated but the value of a clavicular-coracoid screw is not mentioned. Few would care to fix this joint with a Kirschner wire and then immobilise the whole limb in a thoraco-brachial plaster for forty-five days when this simpler method is equally effective. Unfortunately the sole axillary view of a posterior dislocation of the shoulder is the worst reproduced radiograph in the book, and so under-emphasises the importance of this investigation. Insufficient space is devoted to this rare but important lesion, and no mention is made of the fact that reduction is only stable in abduction and lateral rotation. Not unnaturally the Putti-Platt procedure is recommended for recurrent dislocation of the shoulder, but other methods deserve mention.

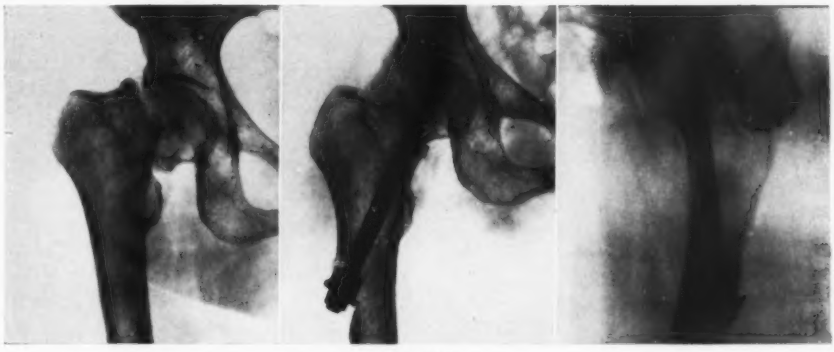

FIG. 816

Patient aged fifty. Result five and a half months after the operation. In this case a nail of the Putti type has been used.

The principles of the long oblique nail for the subcapital fracture are admirably illustrated, but the screw recommended has one fault—namely that it presents too narrow a surface to the downward thrust of the head, and would therefore tend to come out on early weight bearing. It is perhaps for this reason that a hip spica is recommended after operation, a step which very gravely reduces the value of nailing a fracture in the elderly. No reference is made to separation of the upper femoral epiphysis in children, though separation of the lower epiphysis is fully discussed. Treatment of injuries to the menisci and collateral ligaments of the knee follows accepted lines. In fractures of the upper end of the tibia too much emphasis is laid on open reduction and screw fixation, which should be reserved for the exceptional case. In describing fractures of the ankle, a confused and complicated subject, the descriptions of the mechanism of injury are correct but are backed by poor figures in which abduction is mixed up with lateral rotation. In describing fractures the anatomical classification of uni-malleolar and bi-malleolar is preferred, and in consequence where the high Dupuytren fracture is described there is a failure to relate the special characteristics of the fracture to the sequence of ligamentous injury. As the pattern of ankle fracture is determined by the sequence of ligamentous injury, it is only by fully understanding this that the main varieties of injury become comprehensible.

One might well end this review in the tradition of the volume by a list of errors of the reviewer: 1) Failure to emphasise the quality of the printing, typography and illustration. 2) Failure to emphasise one's conviction that this is the best volume on fractures yet published on the Continent. 3) Failure to acknowledge the influence of personal taste on the choice of subjects for criticism. 4) Failure to acknowledge one's inability to devote adequate time and space to a review of such a lengthy volume. —J. G. BONNIN.

BONE DISEASES IN MEDICAL PRACTICE. By I. SNAPPER, M.D., Director of Medicine and Medical Education, Beth-El Hospital, Brooklyn, N.Y. $10\frac{3}{4} \times 7\frac{1}{2}$ in. Pp. x+229, plus 48 pages of plates. Index. 1957. New York and London: Grune & Stratton. Price $15.

This volume will be welcomed by all familiar with Snapper's *Medical Clinics on Bone Diseases*, the second edition of which was published in 1949. The author has continued his researches of the literature and has in fact done a great deal of work in bringing up to date his knowledge of the affections dealt with in the previous volume. He deals fully with their treatment.

This is hardly a book for students or those with no experience of the skeletal errors dealt with, but should be of great service to those with some special experience, particularly when they run against a case of exceptional difficulty or one displaying an unusual complication. One trouble is to follow all the elaborate and deep biochemical statements made or quoted. The first chapter, dealing with the Physiology of Bones, is much too deep for those " in the daily practice of medicine." One wonders how many medical men in this country can appreciate the meaning of the title of the second chapter, viz., Semantics of Bone Disease. The author evidently prefers to discuss the rarer and more complicated types of case rather than the straightforward affections, which in some instances are rather neglected. Fanconi syndrome is very well dealt with, and he includes a good list of references for biochemical details, but his discussion becomes very complicated later, not unexpectedly. An interesting statement is that coeliac disease must last at least two years before bone changes become visible. Osteoporosis and the treatment of its various causes are well dealt with.

One of the best chapters is that dealing with hyperparathyroidism, but not for the student. Again there is an excellent list of references. The author quotes several reports of multiple parathyroid adenomas, in two of which three adenomas occurred, and in one case four adenomas: he has heard of one case with five tumours. In discussing renal osteitis fibrosa the author states that osteitis fibrosa always develops when rapid absorption of bone takes place, regardless of the cause of the bone absorption. In discussing osteitis fibrosa disseminata he claims to have reported, in 1932, the first case of what is now generally called Albright's syndrome, in a girl with widespread osteofibrosis and with brown naevi on face and chest, who experienced her first menarche at seven years.

The chapter dealing with myelomatosis is one of the best: it is up to date and contains a very full discussion of all the latest reports and information. The latest test for Bence-Jones protein he states is " paper-electrophoresis." For Hodgkin's disease, when resistant to x-ray treatment he recommends nitrogen mustard intravenously. His discussion of osteoporosis circumscripta cranii, whether this is or is not a feature of Paget's disease, is not very helpful. He evidently regards most cases showing leontiasis—and at least some without—as cases of Paget's disease. With regard to Gaucher's disease he quotes an article published in 1956 which states that increase of acid phosphatase " regularly occurs " in this disease. Among his radiographs of this affection—all radiographs are together at the end of the book—is one showing typical and well marked osteoporosis of the spine, hardly a good illustration of the radiographic changes seen in Gaucher's disease. The final chapter, dealing with " Differential Diagnosis of Bone Lesions," is very good indeed and could be appreciated by any medical man. The author gives a list of nine affections in which he regards metastatic calcification as a dangerous complication. As a final criticism of this valuable book one must refer to what he says about osteogenesis imperfecta, a bone affection he does not deal with; it was rather a shock to read that " generalised absorption of bone is a constant phenomenon in osteogenesis imperfecta, so-called fragility of bone."—Thomas FAIRBANK.

MODERN TRENDS IN SURGICAL MATERIALS. Edited by Leon GILLIS, *M.B.E.*, M.Ch.(Orth.), F.R.C.S. (Eng.), F.R.C.S. (Edin.), D.L.O. Consultant Surgeon, Queen Mary's (Roehampton) Hospital, East Ham Memorial Hospital and St John's Hospital, London; with twenty-one other contributors. $10 \times 7\frac{1}{4}$ in. Pp. xi+275, with 96 figures and 2 tables. Index. 1958. London: Butterworth & Co. (Publishers) Ltd. Price 72s. 6d.

For more than two hundred years physicians have had their pharmacopoeias in which are specified the characters of the drugs inserted into the human body enterally, parenterally and transdermally. In modern times national authorities have shown interest in sponsoring official publications setting out pharmaceutical nomenclature, methods of manufacture and dosage and have set up schedules of poisons and dangerous drugs. It is, therefore, surprising that so little has been done along similar lines for the materials inserted by surgeons into the human body. True it is that this type of surgery has only been widely practised in the last fifty years; especially during the latter half of this period. The grading of sutures, the testing for toxicity in plastics, the assessment of the

chemical and physical properties of metals and the biological reactions produced by them, the mechanical design of appliances in relation to the forces within the body, in particular the size and shape of screws and the holes in appliances through which they are attached to bone; all these matters have been allowed to remain in a state for which "chaos" is the only right word: an unwelcome price to pay for surgical individuality and enthusiasm.

This state is passing but we have some way to go before there is a detailed list of "Official Materials" which will be accepted as fully tested and approved products, available for those who wish to have such assurance as the scientific knowledge of the time will allow, and which will be subject to strict supervision and periodic revision, as are the medical pharmacopoeias.

The present work does not provide such a surgical "pharmacopoeia." About it there is somewhat the air of opportunism. That it sheds some light upon this important subject is certainly opportune, especially when there is so much activity by several national bodies through the assistance of the British Standards Institute: work which is referred to here only in passing.

It should not be thought, however, that the idea of the present book is new. Paré and Fabricius in the sixteenth and Scultetus in the seventeenth centuries were pioneers in discussing and illustrating the surgeons' armamentarium. The value of the present work is in the scientific discussion (notably that of F. P. Bowden, E. G. C. Clarke, J. Hickman and J. B. P. Williamson) of the background problems, particularly in the orthopaedic context, which takes up nearly half of the book. The rest deals with the materials of abdominal, dental, neurological and vascular surgery; anaesthetic apparatus but not gases; and many external appliances such as hearing aids, artificial limbs, but not artificial eyes, though including frozen corneal grafts. There is a chapter with the title "Material for Splints," but it is very limited in content and merely displays its author's enthusiasm for plastic materials. Strangely there is no mention of leather except as a material for artificial limbs; and steel for external splints is merely referred to in passing. These are real defects in this book, for leather still remains an extremely useful natural plastic material as well as being important as a covering for metal. Knowledge of the methods of using steel and light alloys in external splint making has lately been advanced by standardisation committees and it is a pity that there is no reference to this work here.

For most of us in orthopaedics the sections of this book which are of the greatest interest are those dealing with materials used as implants. These appliances fall into two groups: first, those used to hold sections of bone together while union takes place, as, for example, in fractures or in arthrodesis of joints; second, appliances used as prosthetic replacements for portions of the skeleton that must be excised. An appliance of the latter type usually remains permanently *in situ* and will be exposed to all the static and dynamic force normal to the part being replaced: a biomechanical synthesis is the aim, but surgeons at present are far from achieving it. In the healing of fractures implants merely fix the fragments while natural osteosynthesis occurs. When this happens the implant serves no further purpose.

The implants used must satisfy criteria which are biological, chemical and physical. They should take their place in a biologically fluctuating tissue, the chemical and physical characters of which are also not static. They should cause no biological or chemical reaction in the surrounding tissues nor themselves be subject to undesirable chemical or physical change. They should be free from electrical potentialities. The strength of the material must be fully capable of withstanding the forces to which it may properly be exposed; yet it must be capable of being shaped by casting or machining into appliances of appropriate design. The forces to which appliances are subject are those arising outside the body as well as those of intrinsic muscular origin. Belonging to the former group are the forces applied by the surgeon in introducing an appliance or fixing it in position, particularly by screws.

The corrosion of non-stainless steels is well known because it is everywhere so obvious. Only in recent years have surgeons realised that less obvious corrosion occurs in some of the stainless steels. Those that have magnetic properties are known as martensitic and are unsuitable for surgery. The austenitic steels containing chromium and nickel are best and, if also containing molybdenum (Cr. 18 per cent, Ni. 8 per cent, Mo. 2–4 per cent), provide the most strongly corrosion-resisting properties while possessing strength, toughness and workability. Such steel (BSI No. EN58J in Great Britain and A.I.S.I. 316 in America) is the standard generally accepted. On the surface of the metal is formed a protecting layer of oxide which may be broken down by the exclusion of oxygen in surrounding parts and by changes in the electro-chemical state when combined with dissimilar metals. Micro-corrosion may be productive of untoward clinical symptoms. Amongst non-ferrous alloys that are inert a notable position is held by Vitallium (Vinertia) which is cobalt chrome molybdenum. The surgical importance of corrosion in metal is rightly emphasised in this work, but one notices a tendency on insufficient evidence to discount the influence of sepsis as a feature in the failure of many technical procedures in which metal implants have been used in the past or which have been described in standard text-books. Advocacy of a new idea does not justify discrediting an old one on grounds

of plausibility alone. This may be a quibble but on stronger ground one feels that quite inadequate attention has been paid to the design of parts of appliances especially of plate holes and the screws by which they are fixed to bones. Badly shaped screw heads which inaccurately fit countersunk plate-holes offend first mechanical principles. Lately we have heard much about the corrosion of stainless steel screws as a result of the deposition of minute metal fragments from the unsuitable martensitic steel of screwdrivers; but in this book little is said upon the very real danger of the breakdown of screws from the application of too great a torque by the surgeon through the screw-driver because the hole in the bone has been made with a drill of too small a calibre.

In the past there has been a great lack of animal experimental work before materials have been inserted into the human body. The continuing need for this experimental work is emphasised.

In the discussion of standard materials it is advisable to use a standard nomenclature. Several of the writers in this book use confusing descriptions such as F.S.T., F.M.B., E.M.S., which are all steel manufacturers' trade names and should be avoided. The use of adjectival eponyms is unavoidable: there is no other way of describing a "Judet prosthesis." What, however, is a *worn Judet* (page 90)? Neither of the distinguished surgeons of that name could ever be "worn": or wan!—Norman CAPENER.

RECENT ADVANCES IN CEREBRAL PALSY. Edited by Ronald S. ILLINGWORTH, M.D., F.R.C.P., D.C.H., Professor of Child Health, University of Sheffield; Paediatrician, Children's Hospital and Jessop Hospital for Women, Sheffield. Foreword by Norman B. CAPON, M.D., F.R.C.P., F.R.C.O.G. $9\frac{1}{2} \times 6\frac{1}{4}$ in. Pp. 404, with 136 figures and tables. Index. 1958. London: J. & A. Churchill Limited. Price 50s.

Historically, orthopaedics has been closely linked with the treatment of cerebral palsy: in fact the development of orthopaedics owes much to W. J. Little who himself made a considerable study of the disease and whose influence led to the foundation of the Royal National Orthopaedic Hospital. Until twenty-five years ago almost the only treatment available for this condition was in orthopaedic departments by physical therapy and occasional operative surgery. Since then, fresh interest has been aroused by the work of Phelps and Carlson in the United States. According to Phelps cerebral palsy includes "All those conditions in which interference with the control of the motor system arises as a result of lesions within the brain." It is, however, recognised that, although at one end of the scale such lesions will be associated with severe mental deficiency, at the other end will be found many examples of physical disability more or less severe in children of high and even normal mental capacity. While charitable bodies having a large parent membership have allowed themselves to be over-impressed by the mental potentialities, nevertheless the stimulus of such bodies has caused renewed study of a subject that had previously been relatively neglected. The importance of this new work is far greater than its results in the treatment of cerebral palsy, for undoubtedly it has led to fresh neurophysiological, psychological, physical therapeutic and educational inquiries affecting other fields. As in many new branches of medicine, there has been a tendency to discredit entirely and to neglect the older disciplines. So it has been with the orthopaedic aspects of the care of cerebral palsy. The condemnation of operative orthopaedics and the abandonment of splintage went too far, and the new workers failed to realise that, led by McCrae Aitken and such physiotherapists as Miss Isabel Ainger of Oxford, there were many of us who had come to realise that the correction of deformity and its maintenance with re-education were largely to be achieved without surgical intervention, but that surgery still had a place.

The present work is a most valuable guide to the present knowledge upon cerebral palsy. Professor Illingworth has assembled a good team of experts, and each writes with authority and is interesting: furthermore, each gives a comprehensive bibliography of recent work. Illingworth begins with a classification based upon that of Phelps and discusses incidence and causation. In his careful analysis he draws attention to a little-recognised group of patients in whom the disease is progressive, a circumstance that is most embarrassing in a special school when a child is discovered at the end of its time to be actually worse than when it entered: fortunately a relatively rare thing. Spasticity compared with athetosis is in most reports far the commonest type of case; but in Phelps's group the incidence of the two conditions is equal (40 per cent). In all cases of cerebral palsy there is a high incidence of premature birth, and the principal single etiological factor is anoxia. Cyril B. Courville gives a fine account of the great variety of pathological changes in the brain. The clinical picture and handicaps of affected children are discussed by Illingworth. In the latter connection he quotes other workers upon the relation of eye dominance and handedness; one had thought that Russell Brain had sufficiently discounted any such relationship. A good deal of attention is paid to the sensory defects which are

now being recognised as important contributory features in motor handicaps. This is discussed by A. W. G. Ewing in respect of hearing, and Norah Gibbs deals with the psychological aspects. Eleanor Schonell discusses intelligence testing and educational problems and methods. H. M. Cohen reviews some British institutions for treatment and education, and Alexander Innes describes some of the special equipment that has been developed to facilitate living and education. A very small chapter by Winthrop Phelps deals with physical therapy which is of interest in view of the large scope claimed by physiotherapists. The scope is often that obtained through peculiarly coloured spectacles—and there is little agreement between the various groups about the methods used, though all agree that by frequent intensive individual care they do get results. The question is: how long does it last after the extra brain has been removed from the case? Speech therapy is well discussed, and it is refreshing to find how much emphasis is given to posture, gesture and manual activity as manifestations of speech. G. A. Pollock and W. J. W. Sharrard give an excellent and well balanced account of the orthopaedic surgical possibilities, both in general principles and detailed discussion of particular problems: the correction of deformity, the reduction of overactivity in groups of muscles, the treatment of pathological dislocation. They emphasise the importance of splintage and other methods of overcoming contractures rather than by neurectomy: they also prefer that splintage shall be rigid. Russell Meyers reviews the present position of neurosurgery. The great difficulty is that of localising anatomically the lesions responsible for different types of cerebral palsy, particularly in relation to the newer knowledge of the physiological processes of cerebration. He recalls that during sleep the hyperkinetic and myotonic phenomena of certain disorders are suppressed. We need to know more about the physiology of sleep. " Can we divine what the state of the organism is during sleep and soon after awakening, and, if so, can we duplicate that state in our patients by the use of drugs and/or surgery? These are intellectual challenges as exciting as ever confronted a frontiersman." One feels that in contributing to this and other aspects of neuropathology there is justification for the vast cost of special institutions for the care of such children.

This volume is a worthy addition to the publishers' series of " Recent Advances." Everyone having to deal with children suffering from cerebral palsy must have it.—Norman CAPENER.

REHABILITATION OF THE HAND. By C. B. WYNN PARRY, *M.B.E.*, M.A., D.M., D.Phys.Med., Specialist in Physical Medicine, Royal Air Force; assisted by N. R. SMYTHE, M.A.O.T., Chairman of the Occupational Therapy Association, Head Occupational Therapist, Medical Rehabilitation Unit, Royal Air Force, Chessington; and L. E. BAKER, M.C.S.P., Superintendent Physiotherapist, Medical Rehabilitation Unit, Royal Air Force, Chessington; with contributions from D. A. BREWERTON, M.D., M.R.C.P., D.Phys.Med., and D. BROOKS, F.R.C.S. (I.). 10×7 in. Pp. vii+290, with 101 figures. Tables. Index. 1958. London: Butterworth & Co. (Publishers) Ltd. Price 45s.

The author in his preface calls this volume a cookery book, and it is a good description. It covers the whole field of surgery of the hand, giving an outline of the surgical treatment, and a detailed description of the physiotherapy, occupational therapy, methods of splinting, mobilising and exercising of the hand, and ending with a review of the resettlement programme available for a permanently disabled patient.

There is a valuable chapter explaining the theory of electro-diagnosis. This is unfortunately made difficult to read by an erroneous figure reference number. For the physiotherapist there are detailed instructions, clearly illustrated, for carrying out specific activities with the hand. For the occupational therapist there is a mass of classified suggestions for obtaining and encouraging activity by work and games.

Mr Donal Brooks has written a clear exposition of the principles governing reconstruction of the hand, based on the types of treatment available for each particular cause of disability. There is an excellent section contributed by Dr D. A. Brewerton on the hand in rheumatoid arthritis, in which he oultines the deformities and disabilities, attempts to explain them and lays down rational lines of treatment for each. The surprising point which comes out of the sections on surgery in this chapter is the repetition of the phrase " There are no detailed accounts of the results of such surgery."

The book is well produced and well illustrated, almost entirely with photographs; their quality is good, and the arrangement varied enough to aid the memory. This will be a valuable addition to the libraries of physiotherapy and rehabilitation departments, for it is a real dictionary of information on all aspects of the after-care of hand injuries. Any surgeon who is making the hand his special interest will find it of great value.—H. Graham STACK.

CONGENITAL ANOMALIES OF THE HAND AND THEIR SURGICAL TREATMENT. By Arthur Joseph BARSKY, M.D., D.D.S., Attending Surgeon for Plastic Surgery, Mount Sinai Hospital, New York City; Professor of Clinical Surgery, Albert Einstein College of Medicine, New York City. $8\frac{3}{4} \times 5\frac{3}{4}$ in. Pp. x+165, with 77 figures. Appendix and Index. 1958. Springfield, Illinois: Charles C. Thomas, Publisher. Toronto: The Ryerson Press. Oxford: Blackwell Scientific Publications. Price 43s.

In recent years much work has been done on the nature and origin of congenital abnormalities. In particular, serious thought has been given to the influence of radiation upon the germ plasm and the production of mutations. Aristotle said, " Of a certainty the germ cell is both originator and controller of this child from that parent; these things lie in its nature and there it must develop. Empedocles erred when he said that many of the characters of living forms arise through their environment during development . . . For man generates man and the special characters of the parent determine the same characters in the offspring." It may be that modern research will continue to show that Empedocles was not so wrong as Aristotle believed.

This monograph opens with a review of the present outlook upon the etiology of these distressing conditions and discusses the part played by genetic and environmental factors. The author wisely

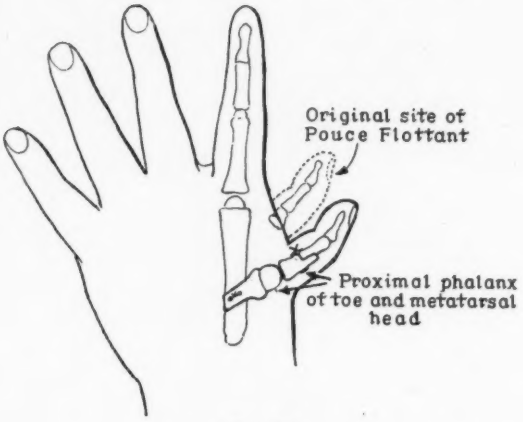

FIG. 58

Operative procedure for the *pouce flottant*. The original site is indicated by the broken line. At the first operation the thumb was migrated proximally on a neurovascular pedicle. At the second operation, several months later, the metatarso-phalangeal joint of the middle toe was transplanted, as shown in the diagram. A lap joint was used to bring the phalanges together, while the metatarsal was wired into a prepared groove at the base of the metacarpal of the index finger. It will be necessary to perform tendon transfers at some future time. In the ten months that have elapsed since operation, the graft appears to be growing satisfactorily, but one cannot predict with certainty its final fate.

offers no clinical classification of hand anomalies, for he points out that many are complex and admit of no detailed grouping. He gives a glossary of the recognised descriptive terms. The numerous illustrations are well chosen and clearly produced.

The work is based upon an analysis of his own clinical experience of 165 cases and a survey of the literature of the past thirty-five years. Each condition—syndactyly, polydactyly, brachydactyly, ectrodactyly, macrodactyly, club hand and others—is considered in detail, and views are expressed upon the principles and technique of treatment. In some cases there is little that can be done, but in many cases there is much that wise and thoughtful surgery can achieve. Those who take this book to heart will find it a useful guide to the intricate problems of malformation. It represents the views of a wise and experienced plastic surgeon and will repay careful study.—R. G. PULVERTAFT.

DIE SPONDYLITIS TUBERCULOSA UND IHRE OPERATIVE BEHANDLUNG. By Dr. med. J. KASTERT, Ärztl. Direktor des Sanatoriums Sonnenwende, Bad Dürkheim/Pfalz. Mit einem Geleitwort von oö Prof. Dr. Med. E. Randerath. $10\frac{1}{2} \times 7$ in. Pp. 187, with 270 illustrations in 157 figures. Index. 1957. Stuttgart: Hippokrates-Verlag. Price DM 64.50.

This book is a record of the use of radical surgery with local as well as general chemotherapy for tuberculosis of the spine by a man whose experience in that field can be equalled by few. He gives the results of 1,007 spinal lesions so treated from among twice that number of orthopaedic tuberculous patients operated upon in the seven years 1949–56.

Dr Kastert tells how, in 1949, he saw the opportunity of draining and eradicating foci of disease as Erlacher had advocated in 1921, but with greater safety; having, however, limited amounts of streptomycin at that time, Kastert sought to concentrate it where it was most needed instead of diluting it throughout the blood and tissue fluids of the whole body: he drained abscesses, excised their linings, curetted bone lesions; and through rubber catheters left in position he instilled daily, for six weeks, streptomycin and later I.N.A.H. Intramuscular and oral chemotherapy followed for a further three months. During the six weeks' instillation the lesion received concentrations of antibiotics 2,000–20,000 times that commonly obtainable in the blood.

He considers that no case is too early for operation if complications are to be prevented and the disease shortened; and that any symptoms or signs of active disease demand operation in any patient under seventy who is not moribund, meningitic or grossly phthisical, or otherwise presents an impossible surgical risk.

Middle and lower cervical vertebrae are attacked through an antero-lateral horizontal incision going in between the great vessels and the thyroid and larynx or trachea. Costotransversectomy is done from one or both sides according to need. If there are two lesions, they may be operated upon both at once or the more extensive may be taken first. The lumbar bodies are approached after transversectomy. Whereas in the thoracic region bilateral paravertebral abscesses often communicate in front of the spine, in the lumbar region they rarely do so and bilateral approach is even more frequently necessary. A " gravitational " abscess may be exposed and cleared from the groin upwards extraperitoneally. The transperitoneal approach is used for lumbo-sacral disease. The catheter is brought out as far as possible through muscle to give a valvular track after removal. One sealed catheter into which the injections are subsequently made by needle is used; a second catheter may be used for drainage if there has been a large abscess; the wounds are otherwise closed completely. Free use is made of tomography before operation and of radiography, with curettes or other guides in position, during operation for the location of every small cavity. Bone chips to pack curetted cavities do not seem to have been used.

The fully developed scheme of chemotherapy now begins with a few weeks of Tibione with P.A.S. 6 grammes and I.N.A.H. 5–10 milligrams for each kilogram of body weight, and then streptomycin $\frac{1}{2}$–1 gramme daily for five to ten days before operation. At operation streptomycin 1–2 grammes and I.N.A.H. 50–100 milligrams are left in the wound. After operation streptomycin $\frac{1}{2}$ gramme daily intramuscularly is given for four and a half months; and for the first two weeks $\frac{1}{2}$ gramme, and the next four weeks $\frac{1}{4}$ gramme, is instilled. For this six weeks 80 milligrams I.N.A.H. is also instilled daily. At the end of the instillation period Tibione is again given with P.A.S. 6 grammes and I.N.A.H. 5–10 milligrams/kilogram daily with the $\frac{1}{2}$ gramme intramuscular streptomycin already mentioned for three months. Mercurochrome 2 per cent is used as a non-irritant skin steriliser during the six weeks that the catheters remain in position. Plaster bed immobilisation was used after operation for four to eleven months (average six months).

The total mortality in the few weeks after operation was 15/1,007; but, in the last 236, only one patient was lost. Three died of meningitis.

Complications included: pleural effusion in seventy-two, usually controlled easily; meningitis in ten; and fistulas or soft-tissue abscesses in thirty-six. These last, sometimes due to inadequate clearance of the focus, demanded a second operation.

Healing was defined as symptomless movement, with normal temperature, E.S.R. and blood picture and radiological fibrous or bony fusion without evidence of any residual focus or abscess. One would have been grateful for a clear definition of the radiological evidence of fibrous " bloch " and the relative proportions of fibrous and bony fusions. No less than 96·2 per cent of the 1,007 patients were considered healed. Nearly 70 per cent of these were said to have reached more than 50 per cent of their normal working capacity.

Of 775 patients in whom the duration of symptoms before operation has been recorded, 293 had suffered up to twelve months, a further 284 from one to four years and a further 202 between four and over twenty years. This is an impressive scatter. Various ages also were well represented.

The book is well printed. There are very many well reproduced radiographs, though in some a detail, such as the outline of a psoas abscess, has to be shown by superimposed white dots. This is a pity, as are such carelessnesses as the occasional reversal of films taken before and after operation or the insertion of prints upside down. It is a slim volume to cover all that could and should come from a study of such a massive series. Moreover, much space is taken by excursions into pathology or rather speculative immunology, not really relevant to the author's *métier*. In consequence, many questions are left unanswered. Apart from the thirty-six sinuses of soft-tissue abscesses demanding further operation, were there no relapses? Some of the illustrations show results such as others have seen with or without operation and certainly without Dr Kastert's special instillation technique. Many of the films show a result stated to be one of several years after operation: how soon in fact was this result obtained? Is this the first film in which it showed itself? We are not told. The difficulty in assessing the value of a method applied by one man to all his patients is that we are still left guessing, and having to reply from our own experience as to which would have done as well with less. Detailed analysis of the results is not given, even of the approximately forty " failures " other than the fifteen who died. What were their ages, lengths of history, or types of lesion? One would like to have similar information about the 962 " successes," and the type of result with speed of fusion, fibrous or bony. There are graphs showing the general scatter of age, length of history, frequency of involvement of individual vertebrae and sex distribution, but there is nothing individual.

The reviewer favours early operation for many patients with Pott's disease; the author's record of the application of operation and instillation chemotherapy to all his patients may be too uncritical for those of us who do not wish to follow a rule of thumb but to do all that is necessary though not more than is required to produce the desired result. One would like to see the method tried first in cases with ramifying and sclerotic disease of some standing or in patients with considerable destruction where it may well be felt that some extra effort is required. The method obviously " works " and, though we may feel some evidence of uncritical enthusiasm, that should not blind us—as it so easily can—to the real value in selected circumstances.—F. Harwood STEVENSON.

SPINAL CORD COMPRESSION. Mechanism of Paralysis and Treatment. By I. M. TARLOV, M.D., Professor of Neurology and Neurosurgery, New York Medical College, New York. $9\frac{1}{4} \times 6\frac{1}{2}$ in. Pp. xiv+147, with 41 figures. Index. 1957. Springfield, Illinois: Charles C. Thomas, Publisher. Oxford: Blackwell Scientific Publications. Price 57s. 6d.

In the first section of his monograph Dr Tarlov discusses an experimental method of producing paraplegia in dogs. By means of an inflatable balloon inserted in the vertebral canal the spinal cord or cauda equina can be subjected to known pressure for a definite time. He found that " functional recovery after acute extradural compression of the cord depends upon the magnitude of the compressive force as well as its duration." With large forces acting for longer than five minutes, recovery did not occur. With minimal force recovery can occur after much more prolonged compression, especially if the force is applied gradually by slow inflation of the balloon. His experiments showed that the nerve roots of the cauda equina are much more resistant to pressure than the cord itself. Very high compression forces applied to the cauda equina for many hours were followed by complete recovery from paralysis and anaesthesia. Histological examination of spinal cords subjected to pressure causing irrecoverable paraplegia showed gross vacuolation and distortion of the long tracts extending over several segments. From these examinations, from clinical observations and from a study of the action potentials recorded from the dorsum of the spinal cord after stimulating a dorsal root Dr Tarlov concludes that paraplegia from compression is due to mechanical distortion of the cord and not to ischaemia. These experiments are ingenious and the results most interesting. In general, they agree with the clinical and pathological findings in paraplegia from compression of the cord or cauda equina in man.

The second section is devoted to a clinical study of compression paraplegia in man, and emphasises the lack of accurate knowledge of the clinical manifestations of acute traumatic paraplegia. Little, if any, clinical evidence is produced to support Dr Tarlov's contention that immediate laminectomy should be performed on all patients suffering from complete traumatic paraplegia with a demonstrable thecal block. This is contrary to the experience of many authorities.

The third section is devoted to the early management of acute paraplegia and is frankly disappointing. The treatment advocated for fractures of the spine associated with cord damage is not in accord with modern practice. Most authorities would condemn as highly dangerous closed reduction of dorso-lumbar fracture-dislocations by hyperextension, and all paraplegia centres have abandoned plaster fixation. Again, Dr Tarlov states that, in unstable dislocations of the cervical

spine, traction by skull tongs should be continued for six weeks to allow time for " firm fibrous union between the injured vertebrae," and that the patient may then be got out of bed and be fitted with an adjustable brace for about three months. Most orthopaedic surgeons have seen redislocation with external fixation continued twice as long as this. The problems of bedsores, bladder and bowel are dismissed in two pages. The monograph would have been better with these omitted.

The importance of this monograph lies in the first section. Further knowledge of the effects of compression of the cord and cauda equina is badly needed, and Dr Tarlov's book is a step in the right direction. The book is beautifully produced and the illustrations are excellent. The publishers are to be congratulated.—F. W. HOLDSWORTH.

PERIPHERAL NERVE INJURIES. By Ruth E. M. BOWDEN, D.Sc., M.B., Professor of Anatomy, Royal Free Hospital School of Medicine, University of London. With a foreword by H. J. SEDDON, *C.M.G.*, D.M., F.R.C.S. $7\frac{1}{4}\times5$ in. Pp. viii+62, with 30 figures. Index. 1958. London: H. K. Lewis & Co. Ltd. Price 8s. 6d.

This admirable little book is intended for " physiotherapists, medical students and housemen, and to be an aide-mémoire to their seniors." It gives the first three groups all they need to know of the subject, and it gives it to them clearly, readably, in commendably few pages, and for a remarkably small price. It is, indeed, a model of what could and should be done about other orthopaedic subjects that lend themselves to this type of presentation. A concise handbook intended for junior people may fairly be criticised on points of detail. Is Professor Bowden convinced that either causalgia or tardy ulnar palsy should be called an " irritative lesion" or that nerves divided in amputations should be injected with gentian violet or " inserted into a hole drilled in the neighbouring bone "? Is she happy in accepting the theory that the intermuscular septum may cause " secondary lesions " after anterior transposition of the ulnar nerve? Ought she to teach the young that causalgia " may be relieved by removal of neighbouring foreign bodies "? These are minor criticisms but, I hope, neither unimportant nor pedantic in a book whose admirable brevity means that it will be read. The author's account of conservative treatment is excellent, and her views on the principles of operative treatment are fairly presented. I enjoyed this little book, and I am recommending it to my students.—D. Ll. GRIFFITHS.

REACTIONS OF RABBIT PATELLARY CARTILAGE FOLLOWING OPERATIVE DEFECTS. A Morphological and Autoradiographic Study. By Hakan CARLSON. $9\frac{1}{4}\times6\frac{1}{4}$ in. Pp.124, with 37 figures and 25 tables. 1957. Acta Orthopaedica Scandinavica, Supplement 28. Copenhagen: Ejnar Munksgaard. Price Da. kr. 32.00.

This useful monograph does much to advance and clarify our knowledge of the reactions of articular cartilage to injury. These were studied by inflicting damage on the patellar articular cartilage in rabbits. The depth of injury, which was confirmed by histological section, never extended beyond the radiate stratum. Avoidance of damage to the subchondral bone ensured the pure reaction of cartilage to injury. The subsequent changes were observed during several months by morphological, histological and autoradiographic techniques.

Because of the absence of mitoses, evidence of regeneration was sought by observing morphological abnormalities in the chondrocytes. Some were regenerative, others degenerative, and the correctness of the conclusions was tested by ^{35}S uptake and by metachromatic staining with toluidine blue. There was reasonably good correlation between the two methods, ^{35}S uptake being assumed to represent active chondroitin sulphate synthesis and metachromasia the actual presence of the substance. It was considered that uptake of ^{35}S (administered as sodium sulphate) was the more accurate method, and the results confirmed the current views that the chondrocytes synthesise chondroitin sulphate and subsequently pass it on to the intercellular substance.

It was apparent that no extensive regeneration took place, because the site of damage was still visible to the naked eye as long as even one year after the operation. As compared with repair in vascular tissues, the whole process is much slower. It is well known that damage to the subjacent bone often produces granulation tissue, and mesenchymal cells from the bone marrow cause considerable regenerative change by undergoing metaplasia into chondrocytes and fibrocartilage. In damage confined to cartilage there was no such change. Degeneration appeared in relation to the damaged area as expected, but regeneration was visible throughout the cartilage, and particularly at the periphery. This peculiarity was ascribed to the better nutrition of the periphery of the articular cartilage, which lies near to the vascular supply of the adjacent synovial membrane. The autoradiographic studies

surprisingly revealed an increased ^{35}S uptake of the undamaged adjacent femoro-condylar articular cartilage; and it was suggested that stimulation by contact with the damaged patellar surface was responsible. It appeared that the greatest regenerative activity came from cells of the intermediate stratum. Previous workers had suggested that the presence of fat globules in chondrocytes indicated degeneration. The findings of the present paper suggest that this is not so and that the globules are frequently seen in normal chondrocytes.

This work will be most valuable in providing basic information for further studies on the abnormalities of articular cartilage in chondromalacia patellae and osteoarthritis. In these conditions the reactions may well be modified, because some fundamental change is probably present which leads to fibrillation of the cartilage and a decrease of chondroitin sulphate.

The author is to be commended on the clarity of his observations, and the work has been most ably translated. A few minor errors, such as " Domiach " for " Doniach " on page 69 and " yong " for " young " on page 67, need not detract from the high standard of production.—George J. CUNNINGHAM.

FRACTURE OF THE UPPER END OF THE HUMERUS. Discussion based on the follow-up of 302 cases. By Fridrik EINARSSON. 9¼×6¼ in. Pp. 215, with 94 figures and 64 tables. 1958. Acta Orthopaedica Scandinavica, Supplement 32. Copenhagen: Ejnar Munksgaard Limited. Price Da. kr. 35.

This is a painstaking monograph by an Icelandic surgeon, based on a detailed review of 302 cases of fracture of the upper end of the humerus treated by at least seven different surgeons in Denmark. The author has gone into every aspect of this problem and has compiled sixty-four tables to show the difference in results between treatment by abduction splintage and by collar and cuff sling. The book opens with thirty-six pages devoted solely to a study of the literature (seventy-nine references) and ends with forty-seven pages of individual case reports (forty-two), including radiographs. Dr Einarsson has proved without doubt that treatment by collar and cuff sling and exercises is followed by better results than by splinting in abduction. His summary on treatment, contained in a delightfully short chapter (two and a half pages) entitled " Suggestions for Therapeutic Schedule," should be read by every practising fracture surgeon, especially those who advocate operation or splinting. Postgraduate students who want to see how well a surgical problem can be investigated would be advised to read this book from cover to cover.—L. W. PLEWES.

OPERATIVE TREATMENT OF ANKLE FRACTURES. By Sverre VASLI. 10×7¼ in. Pp. 74, with 20 figures and 8 tables. 1957. Stockholm: Acta Chirurgica Scandinavica, Supplement 226. Price Sw. kr. 10.

" The aim of treatment in joint fracture is the re-establishment of normal function in the injured joint." From this opening sentence the author proceeds to show that after fracture-dislocation of the ankle this aim is most likely to be achieved by internal fixation and early movement. He operated on 185 ankles (and treated 312 more by closed methods).

The anatomy of the various types of injury is described in clear detail and related to the radiological patterns. The author's recommendation that fragments of the tibia or fibula displaced by 2 millimetres or more should be reduced and fixed is supported by his finding that defective ankles were considerably commoner after incomplete than complete reduction. In the 185 operations the fibula was fixed most often (the figures are not clear), the medial malleolus in 105 and the posterior fragment of the tibia in thirty-seven. Properly used, cerclage wires, screws and marrow nails gave equally reliable fixation, and residual or recurrent displacement was due either to technical shortcoming or to delayed operation. The author does not favour operating on badly swollen ankles, and a third of the operations were put off for ten to fourteen days. He admits, however, that deliberate delay carries the risk of sores and blisters that may take weeks to heal and consequently reduce the ease and success of operation. It may be significant that three of the four deep infections occurred when operation was delayed for a week or more, and necrosis of the skin edges in one-fifth of the cases seems rather frequent. The author favours exercises as soon as possible after operation and, provided the reduction was secure, left the limb out of plaster until movement had been restored and swelling abolished. In a few cases plaster was not used at all.

This is a valuable contribution with clear conclusions and enough information to provide a standard by which other methods of treatment may be judged.—P. S. LONDON.

ZERREISSUNG DES ÄUSSEREN UND INNEREN KNIESEITENBANDES. By Dr Erich JONASCH. 9¼×6¼ in. Pp. viii+88, with 57 figures and 42 tables. Index. 1958. Berlin, Göttingen and Heidelberg: Springer-Verlag. Price DM. 18.60.

I had high hopes on opening this review of learning the answers to three questions: What are the results of conservative treatment? What are the results of operative treatment? What are the indications for choosing one or the other method? As only sixteen patients were treated by open operation in the 1,211 patients treated, there is a lack of detailed pathology and no answer to the last two questions. In ruptures of the medial [tibial collateral] ligament, the opening of the knee joint on the medial side was from 1 to 37 millimetres, with an average of between 3 and 6 millimetres in 453 cases. Conservative treatment, with a form of Unna's paste or with plaster-of-Paris, is considered to have shown satisfactory results, although there is limitation of extension in sixty-seven cases and of flexion in 158, and although only fifteen had no ligamentous laxity. The average time of treatment was eighty-three days. One cannot discover if operative treatment would shorten the time of treatment in a comparable group, or if the end results would be better. It is ironic that, in a book overburdened with figures which should be relegated to the decent obscurity of an appendix, the last figures given are those of two other workers, Ehalt and Öhl (1955), for operative repair in fifty cases of medial ligament rupture. Immediately after this, the final summary states that the correct line of treatment is *always* conservative. The short reference to Ehalt's work shows that, for patients under forty, his views are exactly contrary. We must await a similarly detailed report of cases treated operatively before we have the facts we want at our disposal.—J. G. BONNIN.

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ÉTUDE DE L'OSSIFICATION DANS LES GREFFES DE MOELLE OSSEUSE. By André DANIS. Travail des Laboratoires d'Histologie et de Pharmacodynamie de l'Université Libre de Bruxelles et de la Fondation Chirurgicale E. Dugniolle. Rédacteur: Dr Alfred Dumont. Acta Chirurgica Belgica. Supplement III. 9½×6½ in. Pp. 120, with 61 figures and 7 tables. 1957. Bruxelles: Les Editions Acta Medica Belgica. Price 200 francs.

This book describes an investigation into the osteogenic properties of bone marrow. It begins with a review of previous work, and finds that the results are inconstant and contradictory. The author considers that this is due to faulty technique, and emphasises the dangers of infection and desiccation. Dr Danis has performed a series of experiments, mainly on rats, using a careful aseptic technique. Taking marrow from the femur, and making sure that it contained no bone particles and that it did not become dry, he injected it into the anterior chamber of the eye and studied it both *in vivo*, by injecting sodium sulpho-alizarinate, and histologically. In autologous transplants bone always formed: the bone began in the middle of the graft, spread peripherally and persisted at any rate for many months. Bone marrow treated with alcohol, heat or cold did not form bone; nor did cortical bone. In homologous experiments the results were inconstant. In heterologous experiments bone did not form.

The author concludes that formation of bone from marrow depends on living cells and is not due to induction of metaplasia in the host tissue. He believes that the reticular cells of the marrow are potentially osteogenic.

These results may revive the nearly moribund cellular theory of bone grafting and might affect our operation technique.—Robert ROAF.

ALKALINE PHOSPHATASE AND CALCIFICATION. Histochemical Investigations on the Relationship Between Alkaline Phosphatase and Calcification. By Erik HENRICHSEN. 9×6¼ in. Pp. 85. Index. 1958. Acta Orthopaedica Scandinavica, Supplement 34. Copenhagen: Ejnar Munksgaard Limited. Price Da. kr. 20.

Robison (1923) first suggested that the primary cause of calcification was splitting of phosphoric esters by alkaline phosphatase which resulted in local supersaturation of the tissues with respect to phosphate and calcium ions. So many difficulties arose over the interpretation of various types of experimental results (obtained both *in vivo* and *in vitro*) in terms of this simple mechanism that McLean (1955) was " happy to note that, for the first time in years, it has been possible to sit through

a conference on mineralised tissues without having to discuss the role of alkaline phosphatase in calcification. I have long subscribed to the view that this enzyme is not required to provide phosphate ions for the bone salt . . ."

The author of this review attempts to redress the balance by restating the arguments for Robison's original theory. He has been led to do so by histochemical investigations on the association of alkaline phosphatase with sites of calcification. Although this association is invariable, the author distinguishes between the liberation of phosphatase as an incidental consequence of cell degeneration which results in pathological calcification and its specific elaboration by osteoblasts in pre-osseous tissue. It is still uncertain whether the phosphatase-containing hypertrophic cells in calcifying cartilage should be regarded as degenerative or as specifically differentiated.

The monograph is clearly written and well produced, but it is a great pity that no illustrations are provided of the material on which the argument is based and that no critical discussion of the histochemical methods employed is included. There can be few fields in biological science so full of pitfalls as is histochemistry.—P. G. WALKER.

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ON QUANTITATIVE MUSCLE PROTEIN DETERMINATION. Sarcoplasm and Myofibril Protein Content of Normal and Atrophic Skeletal Muscles. By Einar HELANDER. 9×6 in. Pp. 99, with 19 figures and 16 tables. 1957. Gothenburg: Acta Physiologica Scandinavica, Volume 41, Supplement 141. Price Sw. kr. 18.

This short monograph provides an excellent example of the enormous increase in the significance of the results of chemical analyses of tissues which is achieved when the figures can be related to tissue morphology on the one hand and to physiological function on the other hand. A technique based on differential extraction by salt solutions, has been devised for separating muscle proteins into three fractions. Histological control showed that these fractions were derived from sarcoplasm, myofibrils and stroma respectively and that the yields were quantitative. The metabolic activities of muscle take place in the sarcoplasm, the myofibrils are the contractile units and the stroma acts as a matrix for these elements.

The results are given of analyses obtained from different types of muscle and from the same muscle at different ages or after denervation or immobilisation. The figures are correlated with the histological picture and interpreted in terms of variations in function. The author is commendably critical of his experimental methods and has tested carefully the effect of many variables in the techniques employed. Confidence in the results given by the methods finally adopted is correspondingly increased. A study such as this in which morphology, biochemistry and physiology meet is a model for a new and enlightened approach to the chemical analysis of tissues.—P. G. WALKER.

ON RHEUMATOID ARTHRITIS IN CHILDREN. A Clinico-Roentgenological Study. By Eero SAIRANEN. 9×6½ in. Pp. 79, with 9 figures and 34 tables. 1958. Stockholm: Acta Rheumatologica Scandinavica, Supplement 2. Price Sw. kr. 30. (Edition sold out.)

This study (in English) from the Rheumatism Foundation at Heinola and the University of Turku, Finland, records 100 children with rheumatoid arthritis starting before the age of fifteen. It is written mainly from a radiological viewpoint, the space devoted to this aspect being more than twice that spent on the clinical survey. There is a polyglot bibliography of about 180 references.

The author shows convincingly that radiological change, except periostitis, occurs much later than in adults: other characteristic features of juvenile rheumatoid arthritis included fusion of the cervical spine, subluxation of the hip, brachygnathia and other growth disturbances. Periostitis was the earliest change, occurring at the earliest four months from onset; erosion was not seen in less than two years. Thus the radiological manifestations seem to be much the same in Finland as in England.—E. G. L. BYWATERS.

LA MÉNISCOGRAPHIE EN SÉRIE DU GENOU. Radiologie Osteo-articulaire (1). By S. de Sèze, A. Djian, R. Calop and H. Puchot (Travail du Centre de Rhumatologie Viggo-Pétersen de l'Hôpital Lariboisière et de l'Hôpital Francô-Musulman). Directeur-Rédacteur en Chef: Docteur Jean Garnier. $10\frac{1}{2} \times 8\frac{1}{4}$ in. Pp. 63, with many figures. January 1958, No. 8. Paris: Monographies Médicales et Scientifiques. Price 900 fr.

In the past there has always been some dispute among those who believe in the value of arthrography of the knee whether a positive or a negative contrast medium is the better. The authors of this short monograph have combined the two procedures by injecting both media at the same time. For this they recommend 30 cubic centimetres of air and 5 cubic centimetres of diodone. The knee is then put through a full range of movement to distribute the diodone throughout the joint. There is no doubt that the result is excellent, giving an etched appearance to the menisci. Some of the illustrations, however, look like air arthrograms, suggesting that the diodone has not been adequately distributed. It is mentioned that there must be no fluid in the joint but this point is not emphasised strongly enough. The method of taking the radiographs is basically the same as that described by others. Tangential views are taken of each meniscus, but the number of views—nine—would seem to be somewhat excessive, and the method of widening the side of the joint under examination is rather unnecessarily cumbersome although effective. The authors are wise to confine their diagnosis to lesions of the menisci, for which this procedure is best suited. Our criticisms in no way detract from the value of this book, which describes a good idea and illustrates it clearly.—E. W. Somerville.

THE TREASURY OF HUMAN INHERITANCE. Edited by L. S. Penrose, M.A., M.D., Galton Laboratory, University College, London. Volume V, On Hereditary Digital Anomalies. Part III, The Laurence-Moon Syndrome. By Julia Bell, M.A., F.R.C.P. $12\frac{1}{4} \times 10$ in. Pp. 63, with Pedigree Plates XVII–XXIII, Figures 188–368 and 4 diagrams. 1958. London: Cambridge University Press. Price 20s.

Like other volumes in this valuable series of monographs on hereditary disease, this is a careful and critical review of the literature up to the present time. The author regrets that the bibliography is less complete than she would have liked, but in fact it must contain nearly all the important references to the Laurence-Moon syndrome, for 189 papers are listed here from 1864 to the present day, and 181 pedigrees are illustrated.

It has to be admitted that at present we have no clue at all as to the nature of the primary defect which produces such a varied and bizarre combination of abnormalities, namely adiposity, ocular defects (usually described as retinitis pigmentosa but often with considerable variation), some grade of mental deficiency, genital hypoplasia, and digital anomalies usually in the form of polydactyly. Although it is likely that retinitis pigmentosa is an abnormality occurring late in embryonic development, whereas polydactyly must occur early, the author nevertheless gives reasons for thinking that the syndrome is likely to be due to a single autosomal recessive gene. In all the pedigrees described there are only two in which a parent was affected as well as the offspring, and in one of these two the marriage was between second cousins. This of itself is strong evidence of the recessive nature of the defect. The fact that 45 per cent of siblings are affected in this series may well be due to selection for it is well known that authors tend to publish families in which more than one case has occurred, and, in any event, material collected from propositi will never show normal Mendelian ratios. In this particular disorder it is moreover difficult to know whether the siblings described as obese or mentally deficient were true examples of the syndrome; the occurrence of polydactyly or retinal defect is of course much stronger evidence, and digital abnormalities have often been recorded in siblings dying in infancy. The occurrence of the syndrome bears no relation to maternal age or to birth order. Another pointer to the recessive nature of the gene is the extremely high consanguinity rate amongst the parents, at least 25 per cent of whom were related in the published cases. No patient in the series was older than fifty-five years. It is very rare for either men or women with the Laurence-Moon syndrome to marry. No male patient became a father, though five affected women produced ten children, of whom six survived infancy. The relative sterility is probably only partly due to the hypogenitalism which is often a feature of the disease.

The syndrome varies a good deal from case to case. The diagnosis is usually first suggested by night-blindness and defective vision during childhood, but the actual ocular defects are very varied. Uncomplicated retinitis pigmentosa is probably not due to the same gene. The subnormal mentality cannot be purely ascribed to the visual difficulties. The digital anomaly sometimes takes the form of brachydactyly or syndactyly, though the most usual form is the occurrence of six digits on hands and feet. Associated defects in the nervous system, the heart and the urinary system have been described either during life or at post-mortem examination.

This valuable and authoritative review will become the essential starting point for future workers in this field.—Robert Platt.

SYSTEMIC RETICULOENDOTHELIAL GRANULOMA. By Per WESTLING, Kurt SUNDBERG and Gunnar SÖDERBERG. 9¾×7¼ in. Pp 66, with 32 figures and 1 table. 1957. Stockholm: Acta Radiologica, Supplement 149. Price Sw. kr. 25.

This monograph is based upon the study of sixteen cases of the group of syndromes that have been variously called Hand-Schüller-Christian disease, Letterer-Siwe disease and eosinophilic granuloma of bone. The patients were collected from the clientèle of Radiumhemmet in Stockholm, and the rarity of the syndromes is illustrated by the fact that it took twenty-five years to collect them. There was histological support for the diagnosis in only twelve, and four of the cases presented solitary skeletal lesions. The cases are described in some detail with good illustrations of well reproduced radiographs. The histological illustrations are as good as one can expect from black and white reproduction of stained sections, but they serve more to demonstrate the need for colour in reproducing histology than do such illustrations in many other diseases. The variability of the radiographic appearances is well shown. X-ray therapy is advised; the writers find "little justification" for operative treatment. The authors' conclusion, which will not be questioned by anyone to-day, is that all these syndromes are aspects of the same disease. In this they agree with many previous writers, including, of course, Lichtenstein (1953), whose title "histiocytosis X" they do not adopt, preferring that suggested by Wallgren in 1940. The monograph is well written in good English (though I find one mistake in Latin and another in Greek), and it makes a useful source of information about sixteen cases of what is really quite a rare disease.—D. Ll. GRIFFITHS.

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OUTLINE OF FRACTURES INCLUDING JOINT INJURIES. By John Crawford ADAMS, M.D., F.R.C.S., Consultant Orthopaedic Surgeon, St Mary's Hospital, London, and St Vincent's Orthopaedic Hospital, Pinner; Assistant Editor, *Journal of Bone and Joint Surgery*. Second edition. 8¾×6 in. Pp. viii+268, with 237 figures. Index. 1958. Edinburgh and London: E. & S. Livingstone Ltd. Price 27s. 6d.

The first edition of this book has been received favourably, as was predicted in the review published in the *Journal of Bone and Joint Surgery* in May 1957. The need for a second edition, only eighteen months later, indicates the demand by undergraduates and general practitioners, for whom the book was written. The text has been revised extensively and amplified by new illustrations, a chapter on the special features of fractures in children, and minor additions to many subjects to make them clearer. There is no doubt that this compact text-book on fractures will continue to fulfil a need and we predict that further editions will appear regularly. Mr Crawford Adams is to be congratulated on his ability to keep his book concise and clear, and free from unnecessary details.—L. W. PLEWES.

PICTORIAL HANDBOOK OF FRACTURE TREATMENT. By Edward L. COMPERE, M.D., F.A.C.S., Professor and Chairman of Department of Orthopaedic Surgery, Northwestern University Medical School, Chicago; Sam W. BANKS, M.D., F.A.C.S., Associate Professor of Orthopaedic Surgery, Northwestern University Medical School, Chicago; and Clinton L. COMPERE, M.D., F.A.C.S., Associate Professor of Orthopaedic Surgery, Northwestern University Medical School, Chicago. Fourth edition. 8×6 in. Pp. 448, with 268 figures. Index. 1958. Chicago: The Year Book Publishers, Inc. London: Interscience Publishers Limited. Price 56s.

This handbook on fractures was first produced in 1943. The fourth edition has now appeared in response to a continued demand for a small and compact manual by medical students and general practitioners who have to do their own fracture work. This latest edition includes descriptions of skeletal traction for comminuted Colles fracture, management of necrosis of the femoral head and non-union of fractures of the carpal scaphoid bone. The authors do not claim to have produced a complete volume on fractures and they say in their preface, "The student and practitioner should be aware of the value of definitive treatment that can be obtained through consultation." They have succeeded in keeping the book a small one and the newly added line drawings are well up to the high standard in previous editions.—L. W. PLEWES.

EMERGENCY SURGERY. By Hamilton BAILEY, F.R.C.S., F.A.C.S., F.R.S.E., Emeritus Surgeon, Royal Northern Hospital, London. Seventh edition. 10×7 in. Pp. xvi+1,197, with 1,576 illustrations, many in colour. Index. 1958. Bristol: John Wright and Sons Limited. Price £9, 9s.

This compendious volume upon emergency surgery has reached a seventh edition and nearly thirty-eight thousand copies, which testifies to the regard with which it is held. A companion for the young surgeon as well as for the man in training, it is practical and thoughtful, full of common sense while teaching surgical first principles. The good teacher must appear dogmatic; he often gives an air of infallibility, yet remains a student and is inwardly humble. Hamilton Bailey is of this type and his humility is still found in his charming testimony to his " Masters " whose portraits adorn a frontispiece. There has been no major change in this edition.

In the foreword there is one sentence that particularly catches the eye: " Notwithstanding its manifold tribulations, it is my belief that there is no career that brings greater satisfaction and more lasting interest than that which is reflected in the pages of this book." Which career: the specialist in " Emergency surgery "? We in orthopaedics would answer this exactly as we do in respect of a career in traumatology. In certain emergencies and in remote parts of the world, every surgeon, no matter what his special interest, should be capable of dealing with affairs outside that field, but under normal conditions the surgeon who is specially trained and skilled in dealing with visceral disease should be the one most capable of dealing with emergency problems in that field; and so with cranial, thoracic or skeletal emergencies. Hamilton Bailey's book is written from the point of view of the surgical teacher in a busy city general hospital. In all such there should be a twenty-four-hour service available in orthopaedics dealing at once with the injuries of the locomotor system, the emergencies of which cannot as here be regarded as more or less limited to open fractures. Numerous details are foreign to common practice in Great Britain, for instance the use of the Böhler distraction frame. Furthermore there is much that only by a very wide interpretation can be called emergency surgery, such as the treatment of chronic infection secondary to compound fractures, certain tendon operations including grafting, and operations for spina bifida in infancy. Under the surgery of the hand the descriptions are based upon sound principles although most surgeons would not agree with frequent changing of dressings: they would not agree that the inexperienced surgeon should think that the ban on the repair of tendons in Bunnell's " No-man's-land " can be " lifted " by any but the most experienced surgeons; for other people the correct emergency treatment is closure of the skin only. Who would agree (page 921) that, as an emergency procedure, a flexor digitorum profundus tendon divided just distal to the insertion of an intact sublimis should be sutured after excision of the sublimis? How many of us would allow our juniors to sacrifice the sublimis also in multiple tendon division at the wrist (page 923)? The illustration of Bunnell's " pull-out " suture (Fig. 1,273) is seriously at fault because the loosely tied pull-out wire as illustrated, coming out through the skin at two points, could not in fact pull out the active suture wire. Split-skin grafts are often needed at once where there is wide loss of skin. Nowhere are the methods adequately described; at the same time undue prominence is given to flap grafts of various types.

In the discussion of spinal injuries, a detailed description is given of laminectomy, but no details are given of the open reduction of fracture-dislocations, when indicated, although it is mentioned. Reference here to the work of Holdsworth and of Meurig Williams is suggested for future editions. Also mention might be made of the immediate treatment of acute spinal strain (whether or not due to protrusion of intervertebral disc substance), an event that can be catastrophic to the patient and needs skilful relief as an emergency. Some few paragraphs on the principles of the immediate treatment of the common closed injuries of bones and joints would not come amiss in a volume that clearly is meant as a " midnight companion," although one hopes that in Great Britain consultants in charge of fracture services are readily available at all times for the supervision of this work.

Modifications such as have been suggested might readily be made by the elimination of the irrelevant and the out of date, for instance an illustration on page 762 showing an unnecessary adventure in radiography of the hyperextended spine, with a radiographer getting the full exposure of the x-ray tube.

One is apologetic for making what seem to be carping criticisms of what is a monumental literary achievement.—Norman CAPENER.

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